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PLASTIC MEDIA BLASTING WASTE TREATMENTS

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Plastic media blasting (PMB) of aircraft and aircraft parts is replacing paint removal by chemicals at many Air Force installations. Plastic media blasting has several advantages over chemical stripping, including waste and cost reductions, and reduction of environmental problems and health hazards. The use of plastic media may result in generation of a hazardous waste, however, as evident by plastic media stripping of F-4 aircraft at Hill AFB. The waste is hazardous due primarily to metal contaminant levels exceeding EPA's Extraction Procedure (EP) Toxicity limits for chromium and, occasionally, cadmium. Potential methods to reduce or eliminate the hazardous waste volume were evaluated in an HQ AFESC research project. Laboratory investigations of incineration were demonstrated to provide at least a 90 percent reduction in hazardous waste volume. Laboratory evaluation resulted in identification of an encapsulation method which can make the waste nonhazardous. Fire prevention in plastic media blasting facilities was also evaluated in this project. (Continued on reverse.)						
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Of the 1,500 pounds of waste produced per F-4 aircraft, approximately 10 percent or less are due to paint. Screening cannot efficiently separate the waste into hazardous and nonhazardous waste fractions. Aerodynamic classification was attempted, but was not successful. Encapsulation of the PMB waste using portland cement resulted in a waste which passed the EP Toxicity Test and offers potential for delisting the waste. Chemical treatment using a 10 percent hydrochloric acid leach successfully removes chromium from the waste, but does not remove cadmium. It also makes the waste fail the EP Toxicity Test for lead. It could be used to delist PMB waste which does not contain cadmium or lead. Charring reduced the amount of PMB waste and also resulted in an ash material which successfully passed the EP Toxicity Tests. However, charring may be difficult to have permitted as incineration. Liquid density separation was also shown to make the waste nonhazardous, but may have limitations as a treatment method. Charring and liquid density separation cannot, however, be ruled out as potential methods for delisting the PMB waste. Incineration is being pursued by Hill AFB and may provide a useful method for handling the PMB waste. This study has identified methods which can be further developed to make plastic media-blasting waste nonhazardous.

*Keywords: paint stripping; paint removal; waste disposal;
hazardous waste; incineration; screen separation;
chemical treatment; (etc.)*

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PREFACE

This report was prepared by the New Mexico Engineering Research Institute (NMERI), University of New Mexico, Campus Box 25, Albuquerque, New Mexico 87131, under contract F29601-84-C-0080 (Subtask 4.03 "Plastic Bead Blasting Residue"), for the Engineering and Services Laboratory (AFESC/RDVS), Tyndall Air Force Base, Florida 32403.

The HQ AFESC/RDVS project officer was Capt Raymond Peters. This report summarizes work done between 13 December 1985 and 15 February 1988.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for public release.

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SECTION I INTRODUCTION

A. OBJECTIVE

The objective of this subtask is to determine and evaluate cost effective and environmentally sound disposal and/or resource recovery methods for plastic media blasting (PMB) waste residue and other blasting wastes and to evaluate the fire risk for plastic media blasting.

B. BACKGROUND

Paint stripping can be performed using chemical or physical methods. Chemical methods produce contaminated wastewater, which must be treated. Physical technologies such as blasting generate no wastewater but do produce solid wastes, which present disposal problems. Plastic media blasting of aircraft produces a waste which exhibits an EPA Extraction Procedure (EP) toxicity level of chromium such that the waste is classified as hazardous.

Currently, PMB waste must be drummed and hauled away for disposal. At Hill AFB, the disposal cost is now (late 1987) approximately \$283 per ton. In the first 3 months of 1986 about 43,000 pounds of PMP waste containing paint shipped from F-4 aircraft were generated at Ogden Air Logistic Center (ALC), Hill AFB, and well removed to a hazardous waste landfill by a pollution control contractor at a cost of approximately \$9000. This procedure is an economic and environmental burden. It is the intent of the Congress of the United States, as stated in the Resource Conservation and Recovery Act (RCRA) of 1976, as amended, that the land disposal of waste, whether hazardous or not, should be the least favored form of treatment. Incineration, resource recovery, or treatment to give a nonhazardous waste are preferred alternatives. Research is required to evaluate these processes so that the advantages of plastic media blasting can be realized by all Air Force Commands.

At Hill AFB, the PMB waste from stripping of F-4 aircraft represents only about 25 percent of the total waste blasting residue. Over 1 million pounds of waste blasting residue is produced annually at Tinker AFB. Owing to chromium and cadmium contents, much of the waste blasting residue produced at AFBs must be classified as a hazardous waste. Treatment technologies must be applied to the waste residue from the various blasting operations.

Due to the increasing use of plastic media stripping of aircraft, recommendations for fire protection are needed. This assessment requires evaluation of the burning properties of the plastic media and dust and evaluation of dust concentrations throughout the blasting facility and within the duct system.

C. SCOPE

1. Phase I

Samples of PMB waste from F-4 aircraft paint-stripping operations at Ogden ALC, Hill AFB, Utah were collected. The chemical composition and physical properties of new plastic media and their residue were investigated. A technology survey and literature review were conducted to identify potential disposal and resource recovery methods. The methods were ranked and laboratory experiments were performed to validate and evaluate the various processes. Cost analyses of the most promising methods of disposal for the residue were performed.

2. Phase II

Samples of waste-blasting residue from various operations were collected from Hill AFB. Additional samples were received from Tinker AFB. The chemical composition and physical properties of the various waste blasting residue were reviewed and determined. Separation systems evaluated for PMB waste were tested on appropriate waste residue types and alternative

treatment and disposal procedures were evaluated. A 55-gallon drum of F-4 PMB waste was submitted to Fisher-Klosterman, Inc., Louisville, Kentucky, for aerodynamic classification on their EXL-12 Classifier as a pilot-scale test for separation of the various waste blasting residues.

3. Phase III

Burning properties of the various blasting media and dusts were evaluated to determine burning potential in existing operations. This information was used to make recommendations for enhancing the fire protection of existing and proposed facilities.

SECTION II
TECHNICAL REQUIREMENTS

The following technical requirements were given to the contractor prior to performance of research.

A. PHASE I

The contractor shall collect and analyze information available from plastic media suppliers concerning composition and physical properties of plastic media used by the Air Force for paint stripping. The various paints which could be removed in paint stripping and the plastic medium types shall also be identified.

The contractor shall obtain, containerize, and transport an appropriate volume of actual PMB waste from Hill AFB. The sample volume shall be sufficient for all laboratory testing. The contractor shall conduct tests necessary to determine composition, contaminants, and physical properties of the PMB waste. If necessary, tests shall also be performed on unused plastic media.

The contractor shall review treatment disposal, and resource recovery technologies and identify all methods potentially applicable to PMB waste. This assessment will include a literature review/technology survey and laboratory-scale testing and evaluation. Among the techniques to be considered, shall be incineration (with appropriate flue gas treatment), physical separation of contaminants from plastic media, and solubilization of chromium with further treatment to remove chromium from the liquid phase. The contractor shall rank and recommend those waste residue disposal and/or resource recovery technologies best suited to PMB waste. Bench-scale demonstrations of recommended options shall be performed.

B. PHASE II

The contractor shall obtain, containerize, and transport various waste blasting residue samples from Ogden ALC, Hill AFB, Utah. Sample volumes shall be sufficient for all laboratory testing. Samples should include garnet, walnut shells plus garnet, walnut shells plus plastic media, PMB waste from stripping of wing folds, and various other waste residue from selected operations.

The contractor shall conduct tests necessary to determine composition, contaminants, and physical properties of the various waste residue. If necessary, tests shall be performed on the unused blasting media. The contractor shall establish separation design criteria for the various waste residue based on the results of the previous tasks. Treatment methods shall be evaluated and ranked. A pilot-scale test shall be performed on a 55-gallon drum of waste.

C. PHASE III

The contractor shall conduct burnability tests on unused plastic media and PMB waste to determine the burning properties. Other blasting media and residues shall also be evaluated for burning properties.

The contractor shall obtain dust concentration measurements within the Hill AFB plastic media blasting facility. Dust concentrations should also be measured inside the circulation ducts near the filter systems. Dust particle size distribution shall be determined throughout the facility and inside the ducts especially near the filters.

Based on information obtained from the previous two tasks, the contractor shall make recommendations for fire protection. These recommendations could be used for proposed blasting operations and for existing blasting operations.

SECTION III

ENVIRONMENTAL REGULATIONS

A. HAZARDOUS WASTE

1. Federal Regulations

Authority for the regulation of hazardous waste is given to the Federal government by Sections 1006, 2002(a), 3002, and 3017 of the Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act (RCRA) of 1976, as amended (Reference 1). Regulations of importance in this study which arise from this Act are found in Title 40 of the Code of Federal Regulations (Reference 2). These regulations identify and control the generation, storage, transportation, and disposal of hazardous wastes. Although many exceptions and exclusions exist, in general, a hazardous ("regulated") waste is one which meets the following criteria: (1) It is a discarded solid material, where the term "solid" is used for anything other than gaseous emissions, (2) it is not excluded from regulation, and (3) It is a listed waste and/or has one or more of the characteristics of a hazardous waste. A listed waste is a specific waste stream listed as hazardous in Federal regulations. The characteristics of a hazardous waste are (1) ignitability, (2) corrosivity, (3) reactivity, and (4) Extraction Procedure (EP) Toxicity. Blasting-media waste is regulated because it meets the characteristic of EP Toxicity, which is discussed later in this report.

The Federal government has few regulations regarding specific methods allowed or disallowed for hazardous waste treatment. Air emissions from treatment, however, are controlled. Permits are required for the treatment of hazardous waste streams. Any method may be proposed for treating a hazardous waste, with one exception: regulations are specifically written to prevent a hazardous waste from being diluted by addition to non-hazardous waste streams. Changing a hazardous waste to a small amount of hazardous material plus a much larger volume of nonhazardous material is

within the intent of RCRA regulations, as is changing it entirely to non-hazardous. The small amount of hazardous material must still be disposed of properly.

2. State Regulations

Most of the work discussed in this report concerns blasting media from Ogden ALC, Hill AFB, Utah. Utah has complete authority to process hazardous waste permits. The Utah hazardous waste regulations (Reference 3) run to 400 pages, with a 72-page appendix and follow Federal regulations. When applying for a permit to treat a waste, sufficient engineering data and proof of financial responsibility must be furnished to the Utah Health Department to allow a proper judgement as to whether a proposed system should be permitted. One can expect a wait of about 1.5 years to receive a permit for treating a hazardous waste.

B. AIR QUALITY

1. Federal Standards

The U.S. EPA has declared its intention to add chromium (Reference 4), and cadmium (Reference 5) to the list of hazardous air pollutants for which it intends to establish emission standards under section 112(b)(1)(A) of the Clean Air Act. The considerations are the carcinogenicity and other health effects at existing ambient air exposure levels. As of 7 November 1985 (Reference 6), lead is not on the list of hazardous air pollutants or the list of other substances being considered for addition. Any treatment processes for blasting residue must restrict emissions of chromium and cadmium.

2. Utah Standards

The Wasatch Front region is a nonattainment area for air pollution control. No further degradation of the air will be permitted in waste treatment processes performed at Hill AFB. Any waste reduction process must have minimal potential for air pollution, at least in the areas of particulate matter, sulfur oxides, and nitrogen oxides. In addition to these limits, the State of Utah usually sets air quality degradation standards for individual substances at 1/300 of the workplace standard set by the American Conference of Government and Industrial Hygienists.

SECTION IV

INSPECTION TRIPS AND SAMPLE COLLECTION

All samples obtained during this project are listed in Appendix A, along with analytical results.

A. HILL AFB

Three visits were made to Hill AFB, Ogden, Utah. On 27 March 1986, the facility was given an initial survey and samples of plastic blasting media and waste were obtained for Phase I testing from the F-4 stripping facility, Building 223.

A second trip was conducted on 18 November 1986 and extensive sampling was performed to obtain samples of a variety of wastes for Phase II. Samples of fresh blasting media, used material from waste bins, and recycle material were obtained at five blast areas. Plastic media were collected at Building 223 (F-4 aircraft) and Building 205 (wing folds and other parts). At Building 505 garnet blast medium (landing gear stripping) and aluminum oxide (gun parts) were sampled. Samples of plastic, mixed plastic/walnut shell, and glass bead wastes were collected at Building 507. A mixture of plastic, garnet, and apricot pits was sampled at Building 847 (missile trailers). Building 223, the only blasting facility at Hill AFB to constitute an entire building, is described in Section VI. The other blasting facilities are described in Section VII.

A third trip to Hill AFB was made on 20 and 21 July 1987 to participate in dust concentration measurements. The concentration measurements were made in ducts by the Occupational and Environmental Health Laboratory at Brooks AFB. The data obtained are presented in Appendix C.

B. NAVAL AIR REWORK FACILITY

On 8 May 1987, the Naval Air Rework Facility (NARF) at Pensacola Naval Air Station was visited and the NARF plastic media blasting facility was surveyed. NARF personnel are investigating a methacrylate (acrylic) thermoplastic resin for plastic media blasting. A major problem with the material is that it smears and easily acquires an electrostatic charge, which makes the residue stick to surfaces. The material is being reformulated to take care of the latter problem. NARF chemists believe that methacrylate dust will be more explosive than dust from melamine or urea formaldehyde polymers. Tests are needed to confirm this. One advantage of thermoplastics is that their waste may be self-encapsulated by simple heating under pressure.

The NARF plastic media blasting facility is a small version of the F-4 stripping facility at Hill AFB. When the NARF reclaim system is working, the dust concentration is very large, 150 g/m^3 . The blasting booth contains photoelectric dust concentration measurement apparatuses in the blasting room, in the makeup air, and in the exhaust. The apparatus in the makeup air appears to serve no useful purpose. The dust concentration monitors suffer from dust buildup on the cell windows and often gives a false alarm. The NARF booth also has a carbon monoxide monitor on the incoming air.

Waste material passes from the blasting booth to a cyclone separator. Airborne fines pass over the top of the cyclone to a bag house. The remaining material is separated into three fractions: large waste (nuts, bolts, etc.), waste smaller than 80 mesh, and material to be recycled. Only the airborne fines collected at the bag house fail an EP Toxicity Test. The fraction of such fines relative to the total waste has not been determined. A formaldehyde odor around the NARF facility has been noted.

The observations at the NARF facility indicate that PMB waste may differ greatly in characteristics, depending on the blasting operation.

SECTION V
ANALYTICAL METHODS

A. SCREEN SIZE ANALYSES

An important physical characteristic of the waste dust is the particle size distribution, as determined by screening. The U. S. Standard Series sieves, used in this study, can be designated by either the size of the opening in metric units or by the approximate number of openings per linear inch. Thus a 50-mesh (or Number 50) screen has approximately 50 openings per inch. The openings per inch are used to designate screens in this report. The terms "sieve" and "screen" are used interchangeably. Sieves used in the present study are listed in Table 1.

TABLE 1. U. S. STANDARD SIEVES

Designation, mesh size	Opening, mm	Designation, mesh size	Opening, mm
12	1.20	80	0.180
16	1.18	100	0.150
20	0.850	140	0.106
30	0.600	200	0.075
40	0.425	230	0.063
50	0.300	270	0.053
60	0.250	325	0.045
70	0.212	400	0.038

Since particle size often varies over a wide range, screen openings are usually selected in a geometric ratio of sizes to compress graphical representations. The U. S. A. Standard Series screen openings are in a ratio of approximately the fourth root of 2 between adjacent screens in the series. The ratio for every second screen in the series is the square root of 2, and the opening size of every fourth screen doubles. The logarithms of a geometric progression are equally spaced, so that a screen analysis can be plotted on linear graph paper.

Usually, every other screen will give a series spaced sufficiently close for a good analysis. The screens chosen for most studies reported here were numbers 20, 30, 40, 50, 70, 100, 140, 200, 270, and 400. In the early stages of this work, the 270- and 400-mesh sizes were not available, and a Number 325 screen was used. This size is half way between the Number 270 and Number 400 screens on a log scale.

In the presentation of screening data, both the amount of material passed and the amount of material retained by a screen are given as percentages of initial input. In many cases, the percentages do not add up to 100 percent owing to losses, rounding error, and measuring error. The percentage of material retained on a screen depends on the preceding screen used. For example, using a Number 50 screen followed by a Number 60 will generally give a different percent retained on the Number 60 screen than will a Number 40-Number 60 combination. All percentages are based on the total amount of material used in the study, not on the amount of material actually entering a screen. Material passing a Number 40 screen is designated as "-40" material. Similarly, material retained on a Number 40 screen is designated as "+40." A fraction passing a Number 40 screen and retained on a Number 60 is designated as "40 X 60" or "-40,+60."

Graphs were prepared to analyze and compare screening data. Since a cumulative plot of material on or through a series of screens does not adequately show the changes in amounts collected on each screen, individual plots were also prepared, in most cases. When a constant ratio of openings

is used, a simple bar graph of amounts retained is correct. However, when the ratio of sizes is variable, it is necessary to adjust the height of the bars such that the areas are proportional to the amount retained. When this is done, the same general shape of plot will be obtained no matter how many screens are used, or what sizes were chosen. On individual plots, the bar height at either end is undefined unless the limiting sizes (small and large) are known or can be estimated.

Cumulative plots of percent retained, or percent passed for a series of screens usually curve at either end. This can be partially corrected by the use of log probability paper, with the cumulative weight on the probability axis. However, it is just as convenient to plot both cumulative and individual amounts on separate sheets. The individual amounts plotted against the screen opening range are actually the slopes of the cumulative curve at each screen size. It is easy to see the effects of poor screenability, or the combination of materials with different size distributions, by observing uneven distributions on the individual plot. Thus, when the fines of Sample 5 were dried and rescreened, the uneven distribution for 140 to 325 mesh was almost eliminated, and the plot became more regular. This can be observed on a log-probability plot, but is much more obvious on the bar graph of individual sizes.

Sieve sizing of solid particles was intended to help determine the location and distribution of the material which would cause the bulk waste to fail the EP Toxicity test. It was hoped that the paint would appear as very fine dust. In such a case, the bulk of the waste material would be coarser than the paint.

B. ELEMENTAL ANALYSES

1. Total Metals

Two types of elemental analyses were performed: total metals and Extraction Procedure Toxicity testing. In a total metal analysis the waste

is digested to allow a determination of the total concentration of a metal, reported in micrograms per gram or parts per million by weight (ppm). Total metal analyses were performed by EPA procedure 3050 (Reference 7), digesting the waste with a concentrated nitric acid and 30 percent hydrogen peroxide solution until all oxidizable material was destroyed. Data from total metal analyses can be used to determine the maximum concentrations possible in the liquid extracts obtained in Extraction Procedure Toxicity Tests (see below). The total amount of each element in parts per million divided by 20 is approximately equal to the EP Toxicity value if all of that element were removed.

2. EP Toxicity Test

The Extraction Procedure Toxicity Test (designated "EP Toxicity Test" in this report) is mandated by the United States Environmental Protection Agency (EPA) under the Resource Conservation and Recovery Act (RCRA) as one of the tests to be performed to determine whether a waste is hazardous (Reference 8). In the EP Toxicity Test 100 grams of a solid are extracted with 1600 mL of water adjusted to pH 5 ± 0.2 with acetic acid. After the final volume is adjusted to 2 liters, the concentrations (usually in units of milligrams per liter) of eight elements are determined. If the concentration of any element of concern in the waste extract exceeds a maximum established by the EPA, the waste is regulated as hazardous.

The early laboratory determinations included all eight metals listed in the EP Toxicity regulation. EP Toxicity Tests of Sample 1 showed that five metals - silver (Ag), arsenic (As), selenium (Se), mercury (Hg), and barium (Ba) - were present in extracts in amounts well below regulated maxima (Table 2). Analyses for these elements were discontinued in most cases. Although the early testing also showed lead contents to be small, lead concentrations were often determined, owing to knowledge that lead-based coatings were still present on some aircraft.

TABLE 2. EP TOXICITY TEST ON SAMPLE 1

Element	Concentration, mg/L	
	Measured	Allowed
As	<0.05	5.0
Ba	0.51	100.0
Cd	0.32	1.0
Cr	10.06	5.0
Pb	<0.05	5.0
Hg	0.002	0.2
Se	<0.01	1.0
Ag	<0.05	5.0

3. Toxicity Characteristic Leaching Procedure

The Toxicity Characteristic Leaching Procedure (TCLP, Reference 9) has been proposed by the EPA to replace the EP Toxicity Test. The TCLP has been developed to better mimic the leaching of toxic metals from waste in the presence of municipal garbage and other wastes in a landfill. A review of the proposed TCLP indicates that the changes in the EP Toxicity test will make no significant difference in the amounts of metallic elements leached out of blasting wastes. The TCLP makes two major changes: the use of a buffered acetic acid mixture, which will make pH control easier, and the addition of a number of organic compounds to the list of materials to be determined in the extract. Though not directly related to the present project, it is recommended that testing be performed to ensure that blasting waste does not fail the TCLP, owing to the addition of these organic materials.

4. Laboratories

In the initial studies, four laboratories were used for the elemental analyses. The laboratories and their identifying codes are the Air Force Weapons Laboratory at Kirtland AFB, New Mexico (WA), the contractor's in-house laboratory at the University of New Mexico (HU), and two outside commercial laboratories (JE and BU). Laboratory WA used argon Inductively Coupled Plasma Spectroscopy (ICPS); the remaining laboratories use Atomic Absorption (AA). Laboratories JE and BU used AA graphite furnaces, which allow extra precision. Laboratory HU used AA without a graphite furnace, but employed a hotter nitrous oxide - acetylene flame and added an alkali metal to eliminate chromium interference. A large variation between laboratory results soon became obvious. Examination of data showed that Laboratory BU had unacceptably low precision. Further data examination (Appendix B) indicated that analyses from laboratory JE were not as reliable as desired.

To compare results from laboratories WA, HU, and JE directly, a standard liquid sample was prepared to reflect typical analyses expected for EP Toxicity testing. For chromium, Analytical Reagent (AR) grade potassium dichromate was weighed out and the solution was standardized by titration against ferrous ion. Cadmium was added using AR grade cadmium oxide. A sample of lead shot of known purity was cleaned with nitric acid, washed with acetone and distilled water, weighed out, and dissolved in a mixture of nitric and hydrochloric acids.

The analytical results on the standard are presented in Table 3. Laboratory JE revised the concentrations first reported due to errors in their calculations. In earlier work, laboratory JE also submitted results which were found to contain calculation errors. In all cases, results were revised only after the laboratory was contacted about unusual values. The revised values reported by laboratory JE for both cadmium and chromium were low. Laboratory WA reported a high value for chromium; however, the other two analyses were close to the known values. Laboratory HU was very close

on all of the analyses and was, therefore, selected for all subsequent work. Although the reliability and/or precision of laboratories JE, WA, and BU are not as high as those of laboratory WA, some results from these laboratories are presented. In no case was a major decision made on unconfirmed data from only one laboratory other than laboratory HU.

TABLE 3. COMPARISONS OF LABORATORY ANALYSES ON PREPARED STANDARD

Element	Concentration, mg/L				
	Standard	Lab JE ^a	Lab JE ^b	Lab WA	Lab HU
Pb	0.5	28.3	0.44	<0.5	0.49
Cd	1.25	52.4	0.7	1.2	1.25
Cr	11.5	32.3	8.0	14.0	11.0

^aValues initially reported by laboratory JE.

^bValues revised by laboratory JE.

SECTION VI
PHASE I: F-4 PMB WASTE

A. F-4 AIRCRAFT BLASTING OPERATION

An excellent overview of plastic media blasting within DOD facilities is given in Reference 10. Stripping of F-4 aircraft at Hill AFB is performed in Building 223, a building which itself constitutes the blasting booth. F-4 aircraft are brought into the facility, prepared, and stripped with plastic blasting media using an operating pressure of 40 psi. Used media fall through grates in the floor and are pneumatically conveyed to the Bin Vent dust collecting unit manufactured by Farr Corporation. This system is rated at a nominal $547 \text{ m}^3/\text{min}$ ($19,333 \text{ ft}^3/\text{min}$). Royce Mechanical Systems of Ogden, Utah, which installed the complete dust-processing system, reports that the induced draft fan on the outlet of the filter house is powered by a 150-horsepower motor, and can pull $1218 \text{ m}^3/\text{min}$ ($43,000 \text{ ft}^3/\text{min}$) against a pressure drop of 15 Torr (8 inches of water). These operating parameters are sufficient to allow a cyclone to be placed before the filter section.

In the Bin Vent, a vibrating 50-mesh screen was originally installed just above the tapered portion of the Farr unit, to separate the dust into reusable +50-mesh material and -50-mesh waste. This 50-mesh screen was in place during all sample collection for this project; however, this screen has since been replaced with a 60-mesh screen. Recycled material is sent to an input bin for the pressure pots, which accept the material and convey it under pressure to the blasting hoses to be used again. The dust collection system contains 50 filter cartridges with a total dust collecting area of 1115 m^2 ($12,000 \text{ ft}^2$). These filters are used to collect very fine airborne dust before recirculating the air and are periodically cleaned by pulsing at intervals. The fines released from this pulsing are allowed to drop into the primary waste bin, along with the fines which passed the 50-mesh screen.

Limited material balance information on the blasting process indicates that medium is used at a rate of 247 kg/hr (544 lb/hr) per gun, at the normal pressure of 40 psi. Normally, three guns are used at one time. Usually, 24 gun-hours are needed, but this may extend to 36 hours if inexperienced operators are used. The target time is 18 hours.

The total weight of media from the guns is equal to 5922 kilograms (13,056 pounds). Since about 680 kilograms (1500 pounds) of PMB waste are produced, this means that the plastic is used more than eight times before it is too small, and passes through the screen. It has been assumed that when return dust spills over the screen, carrying reusable media into the waste bin, more waste is produced, and therefore more fresh media must be added to make up the lost weight.

B. PLASTIC BLASTING MEDIA

The media used at the F-4 stripping facility are obtained from U. S. Technology Division of U. S. Plastics and Chemical Corporation, which manufactures three types of plastic blasting media: Polyextra, a polyester styrene with a Mohr hardness of 3.0; Polyplus, an alpha cellulose filled urea formaldehyde with a hardness of 3.5; and Type III, a urea melamine formaldehyde resin with a Mohr hardness of 4.0. Urea and melamine formaldehydes are highly crosslinked condensation polymers. These two polymers are thermosetting, do not melt, and decompose upon heating. The intermediate hardness medium, Polyplus, is now used for F-4 stripping. Both 20- by 40-mesh plastic medium and a mixture of 30 percent 12- by 16-mesh and 70 percent 30- by 40-mesh medium have been used. Other media have also been used experimentally.

Microscopic pictures of Polyplus medium at magnifications of 6 and 60 reveal that the unused medium particles are of several different colors. The multiple colors of the particles are due to the fact that this material is produced from plastic waste. It is then crushed and screened to the sizes needed by purchasers.

A sample of fresh medium, nominally 20 by 40 mesh, was crushed in a Micro-Mill manufactured by Bel-Art Products, Pequannock, New Jersey. The medium was very difficult to crush; a mortar and pestle could crush only a small amount of material at a time. After multiple passes through the Micro Mill, only about 55 percent of the material was small enough to pass through a 50-mesh screen. The amounts retained on 50-, 100-, and 200-mesh screens, and on the pan were, respectively, 45.0, 17.8, 8.1, and 29.0 percent. The mill does not break the plastic particles, but knocks the corners off, a fact indicated by the large amount of very fine material produced and the persistence of particles larger than 50 mesh.

Fresh media were also run through a laboratory crusher which uses a rotating, knurled disc. Very little effect on the media could be observed. Table 4 gives EP Toxicity Analyses of the two crushed plastic medium samples. These data are presented as controls for EP Toxicity Analyses on waste material. The small amounts of lead, chromium, and cadmium may be due to pigments in the plastic material, since the total ash content of the medium is 1.94 percent. The fact that larger metal concentrations were found in the media processed by the Micro-Mill is probably due to better extraction efficiency with a lower particle size.

TABLE 4. EP TOXICITY TEST RESULTS ON UNUSED PLASTIC MEDIA

Element	Concentration, mg/L	
	Crushed in Grinding Mill	Crushed in Micro Mill
Cd	0.12	0.1
Cr	<0.01	0.4
Pb	<0.05	0.2
Ba	0.72	---

C. PAINTS AND COATINGS

1. Pigments

Colors containing chromium or lead are limited to yellow through green. Blue, maroon, silver, gray, black, red, or white need no lead nor chromates. Among the chromium-containing pigments are Chrome Green, Light or Medium Chrome Yellow, and Shading Yellow. Greens are obtained by adding Iron Blue to yellow chrome pigments. Olive Drab contains Medium Chrome Yellow or Orange, and Shading Yellow, along with other pigments. Molybdate Orange, also called Lead Chromate Molybdate, is the major pigment in International Orange and Insignia Red, which are used in much less volume than greens.

Chrome Orange formulations (Reference 11), also referred to as basic lead chromates, are co-precipitated lead chromate/lead oxide compounds. The ratio of PbCrO_4 to PbO is about 80:20 for light orange, and 60:40 for dark orange. Molybdate orange is a precipitate of lead chromate, lead molybdate, and lead sulfate. The typical ratio of PbCrO_4 : PbMoO_4 : PbSO_4 is 80:15:5. These pigments are all orange to reddish orange.

Light (or Lemon) and Medium Chrome Yellow, Shading Yellow, and Primrose Yellow are different versions of straight lead chromate. The shade can be made greener by addition of small amounts of lead carbonate or lead sulfate. Thus, a Lead Chromate/Lead Sulfate Shading Yellow also exists.

2. Paint

In the past, the top coats of paint on F-4 aircraft were lacquer-based vehicles, which contained lead chromates for yellow and green colors. The light green lacquer contains Chrome Green, Light or Medium Chrome Yellow, and Shading Yellow, along with various nonchrome pigments. The exact formulation and usage rates of the old paint systems were not obtained. However, a lacquer usually refers to a thermoplastic which is

soluble in a particular solvent system, and which may be extended with cheaper resins. Aircraft were repainted as many as three times without stripping the old paint. It is still possible for an aircraft with four lacquer-based coating systems to be scheduled for stripping. This conclusion is based on the stipulation of a 4-year repainting cycle. Since lacquers and lead chromate primers were phased out less than 4 years ago, many F-4 aircraft still have the old paint system.

DeSoto, Inc., Des Plaines, Illinois, sent data sheets for the paint now being used at Hill AFB for the dark green camouflage system. The epoxy primer and the light and dark green were identified by the manufacturer's designations on the paint cans or invoices.

The gray paint used on F-4 aircraft was identified only by the Federal color specification, and DeSoto was not able to identify the specific formulation immediately. Instead, Material Safety Data Sheets (MSDSs) on six other formulations manufactured by DeSoto were obtained. The Gunship Gray shade may be similar to the dark gray actually being used. None of the gray formulations contain any chromates or lead. The color is obtained by adding carbon black to various white or colorless materials. Aircraft painted silver gray or gray would not add any lead to the PMB waste, and the only chromium would come from the primer. This would significantly lower the average levels from those obtained with green paint.

The present painting system at Hill AFB for camouflage is yellow primer, one coat of dark green, and a camouflage design created by coats of light green and dark gray. The paints are identified in Table 5.

The yellow epoxy primer contains 15 percent strontium chromate. Because the hiding power or color intensity of a primer is not important, the formulation needs no additional pigments to intensify the color.

The two DeSoto green paints contain both lead and chromium. The light green paint contains 15 percent lead chromate. The dark green paint contains 5 percent lead chromate and less than 5 percent of lead chromate molybdate. On the MSDS, the designation "<5%" indicates 1 to 5 percent. The best available greens are combinations of chrome yellows with iron blue. These pigments have good intensity and hiding power, are easy to manufacture, and mix well with paint oils, resins, and solvents. In addition, the oxidizing chromates inhibit corrosion of aluminum substrates.

All of the green and gray formulations supplied by DeSoto, Inc., for the F-4 paint system are based on polyesters or modified polyesters, according to the MSDSs. The designation of the primer as urethane compatible does not rule out compatibility with other materials.

TABLE 5. F-4 AIRCRAFT COATINGS NOW USED AT HILL AFB

Color	Federal specification	Manufacturer's code (DeSoto)	Vehicle composition
Yellow	---	513X384	Epoxy, urethane compatible
Light Green	34102	825X313	Modified polyester
Dark Green	34079	825X312	Polyester
Dark Gray	36081	---	Polyester

3. Amounts of Paint Used

The amounts of paint needed for one F-4 aircraft are 15.1 liters (4 gallons) of yellow primer, 30.3 liters (8 gallons) each of light and dark green paint, and 22.7 liters (6 gallons) of dark gray paint. Not all of the paint solids appear on each MSDS; however, the total solids may be

calculated by subtracting the reported solvent weights from the total weight. The solvent contents are given in Table 6. In some cases, a weight range of "1 to 5 percent" was given on the MSDS. In those cases, an average of 3 percent was assumed. For three paints, the total calculated solvent volume was approximately equal to the volume listed on the MSDS. The light green paint, however, was short on solvent volume.

TABLE 6. SOLVENT CONTENTS OF F-4 COATINGS

Solvent	Density, kg/L	Content, % by weight			
		Primer	Dk. green	Lt. green	Dk. gray
2-Ethoxyethyl Acetate	0.975	--	--	15	15
Butyl Acetate	0.882	15	10	5	5
Ethyl Acetate	0.901	--	15	<5	5
Methyl Isobutyl Ketone	0.802	--	10	5	5
Methyl Ethyl Ketone	0.805	20	<5	5	5
Cyclohexanone	0.948	10	10	--	--

4. Amounts of lead and chromium

The amounts of lead and chromium in the total paint system, and the amounts per square meter of surface were calculated. Since the amount of lead chromate molybdate in the dark green may range from 1 to 5 percent, an average of 3 percent was assumed. On an entire F-4 aircraft, the total amount of lead (all in the two green paints) for each paint system is 5.45 kilograms (12 pounds). The total chromium (in the primer and two green paints) is 2.0 kilograms (4.5 pounds). The minimum inorganic content of the paint is 29.1 kilograms (64 pounds). The total weight of paint solids,

including resin, pigments, fillers, and carbon black is 68.6 kilograms (151.2 pounds). The solids volume is 39.7 liters (10.5 gallons), so the average paint solids density is 1.73 kg/L (14.4 lb/gal). The total area of the aircraft, including wing folds and rear stabilizers is 227.6 m² (2450 ft²). Using the conversion factor of 1000 mm-m²/L (1604 mil-sq ft/gal), this calculates to an average paint thickness of 0.174 millimeter (6.9 mils - 0.0069 inch). The data are in Tables 7 and 8.

The total amount of lead in one painting was estimated from the volumes of coatings used, the liquid density, and the listed percent of each pigment. Lead and chromium contents averaged about 8.0 and 3.0 percent of the paint solids, respectively. The total dry paint per aircraft is 68.6 liters (151 pounds) for a complete painting with all coatings. This is 10 percent of the estimated waste dust production per aircraft. The amount of paint on the aircraft may be somewhat less than the actual amount used due to overspray or other waste.

TABLE 7. LEAD AND CHROMIUM CONTENTS OF COATINGS

Pigment	Pigment content, % by weight			
	Primer	Dark green	Light green	Dark gray
Lead Chromate	--	5	15	--
Lead Chromate Molybdate	--	<5	--	--
Strontium Chromate	15	--	--	--

TABLE 8. COATINGS DATA

	Density,		Solvent	Solids		Volume per F-4	
	kg/L	lb/gal		kg/L	lb/gal	liters	gallons
Primer	1.17	9.9	63.9	0.621	5.28	15.1	4
Dark Green	1.19	10.1	60.3	0.654	5.56	30.3	8
Light Green	1.21	10.3	58.5	0.727	6.18	30.3	8
Dark Gray	1.20	10.2	57.1	0.709	6.02	22.7	6

5. Chromium Conversion Coatings

An additional source of chromium in the waste dust is the preparation of aluminum surfaces. An acid chromate solution accelerated by a chemical such as a ferricyanide is applied to the surface and is allowed to react for several minutes before being washed off. Accelo-Gold, supplied by the Turco Products division of Pennwalt Corporation, Los Angeles, California and Alodine, supplied by Amchem, Ambler, Pennsylvania are two such products.

The Turco product produces a coating weight of 0.484 g/m^2 (45 mg/ft^2). Amchem specifies application rates of from 0.054 to 1.61 g/m^2 (5 to 150 mg/ft^2) for different versions of their product. Amchem states that the final compound is ready for painting, and estimates a chromium content of 26.8 percent. Other components of the coatings are aluminum, iron, cyanide, and water. At a coating weight of 0.484 g/m^2 (45 mg/ft^2), the EP Toxicity Test from this source alone would show 2.2 mg/L of chromium in the extract, if all of the coatings were removed by the stripping operation and if all of the chromium was extracted. Since, however, the total amount of chromium in the conversion coating is only 30 grams per aircraft, or 1.5

percent of the chromium in the paint, only a small fraction of the available chromium in the paint film needs to be dissolved to equal the maximum amount of chromium which could be extracted from the conversion coating. In fact, the corrosion resistance of Zinc Yellow, a hydrated double salt of zinc and potassium chromates, is attributed to its basicity and to the chromium ions released because of its slight water solubility (Reference 12). Strontium is similar to zinc in its chemical properties, and its chromate is also slightly soluble. Thus, these slightly soluble pigments probably contribute much more chromium in the EP Toxicity Test than do the conversion coatings.

6. Alternate Pigments

If suitable replacements for chromate pigments could be found, both lead and chromium could be completely eliminated from the paint system. However, more than correct colors and good hiding power are needed. In addition to having these properties, chromate paints provide corrosion resistance, low cost, ease of manufacture, heat and light stability, and compatibility with the desired vehicles (resins plus solvents).

At least two types of green pigment not containing chromium are available (Reference 12). A calcination product of cobalt and titanium dioxide is available in a leaf green, a lawn green, and one other bright green. It is not difficult to obtain an olive drab from bright greens. Addition of an iron blue and/or an iron oxide may work. Colors are easily darkened when needed by addition of carbon black. A second series of greens contains only cobalt, nickel and titanium dioxide. These are relatively innocuous materials. Cobalt and titanium dioxide are not listed as hazardous by the RCRA regulations. Nickel and all compounds of nickel not otherwise specified are on the list of hazardous constituents, but nickel is not part of the EP Toxicity list of elements to be controlled.

Two inorganic yellows not containing lead or chromium are also available (Reference 12). Synthetic Yellow Iron Oxide and Nickel Titanate Yellow are inferior to chromates in tinting strength, and the iron oxide is also inferior in hiding power. In a primer, these qualities are not critical; however, corrosion resistance due to the presence of chromium ions is lost. It would be desirable to determine whether the conversion coatings alone provide corrosion resistance with a nonchromate primer.

Another consideration in substitution of pigments is that titanium-based pigments are usually used in house paints for good hiding power and chalk resistance. Much information is available on titanium dioxide in water-based paints using oleoresinous media (drying oils such as linseed oil, and resins such as reactive phenolics), but much less information on synthetic polymer vehicles. Titanium dioxide-based pigments can be used to color plastics (Reference 13), but absorbed water must be very low, and pigments may have to be milled first with an oil which adsorbs to the solid and makes it hydrophobic. Thus, switching pigments is not a simple process, and some research is needed.

Chromium pigments will be used into the foreseeable future, and lead may always be present in relatively large amounts. However, lead is evidently not be a problem with the present EP Toxicity test. Cadmium in the PMB waste comes from the corrosion-resistant coating on fasteners. Changes to eliminate this cadmium coating are now in progress.

D. PMB WASTE

Data developed at Hill AFB indicate that it costs about \$283 per ton for removal of PMB waste. The waste is not placed in containers for transportation. It is pneumatically removed from the waste bins and emptied into tank trucks.

The PMB waste is usually classifiable as hazardous under RCRA regulations owing to metal contaminants picked up during use. Plastic blasting media used for F-4 aircraft pick up chromium and lead from paint and cadmium from plating on screws. The discarded PMB waste usually fails EP toxicity tests for chromium and, less often, cadmium. Microscopic inspection of the waste indicates that paint flakes and plastic remain separate in the waste. For example, microscopic examination of Sample 5 screen separated waste fractions at 6 and 60 power showed no paint dust sticking to the larger particles of plastic, nor the presence of any visible paint flakes. On the other hand, examination of very fine material separated by the Sonic Sifters Division of ATM Corporation (see below) showed large amounts of paint in the 20-micrometer range. For these reasons, it was hoped in the initial stages of this project that the chromium-bearing paint flakes could be physically separated from the PMB waste.

E. SCREEN SIZE ANALYSES OF PMB WASTE

1. Primary Waste

A 4-pound sample (Sample 1) of PMB waste from the F-4 stripping facility at Hill AFB was received on 22 February 1986. The sample was blended by rolling on a large sheet of paper and was split into four equal parts. One part was crushed in a Bico Pulverizer. About 80 grams of fines were lost during the handling and a larger percentage of +50-mesh material and a slightly lower percentage of -100-mesh material were present in the processed sample than were present in the material as received. A screen size analysis of Sample 1, both as received and crushed, is presented in Table 9. A plot of the cumulative percent passing as a function of screen size is shown in Figure 1.

Sample 1 contains 36.6 percent material coarser than 50 mesh. Sample 4, received later, also contains a large percentage of +50 material (Table 10 and Figure 2). These wastes are not believed to be representative

since the 50-mesh screen in the bottom of the filter unit in the Hill AFB F-4 stripping facility should return coarse material to the blasting units. Following adjustment and maintenance of the facility, a more representative sample (Sample 5) was obtained. The screen size analysis for this sample is shown in Table 11.

The +50-mesh material is down to about 11 percent in Sample 5, a more reasonable value. However, even in this case, it is obvious that the recycling system in the F-4 stripping facility is not operating efficiently. Material is overflowing through the shrouds and some coarse material is being lost to the waste bin. Such overflow greatly affects waste variability.

TABLE 9. SCREEN SIZE ANALYSIS OF SAMPLE 1

Screen size, mesh	As received ^a		Crushed ^b	
	Retained on screen, %	Cumulative passing screen, %	Retained on screen, %	Cumulative passing screen, %
50	36.60	63.40	39.01	60.99
80	31.01	32.39	33.91	27.08
100	6.71	25.68	7.24	19.84
140	8.91	16.77	8.32	11.52
200	5.38	11.39	4.66	6.85
325	6.86	4.53	4.13	2.72
Pan	4.01	0.0	2.13	0.0

^a Average of four samples.

^b Average of three samples.

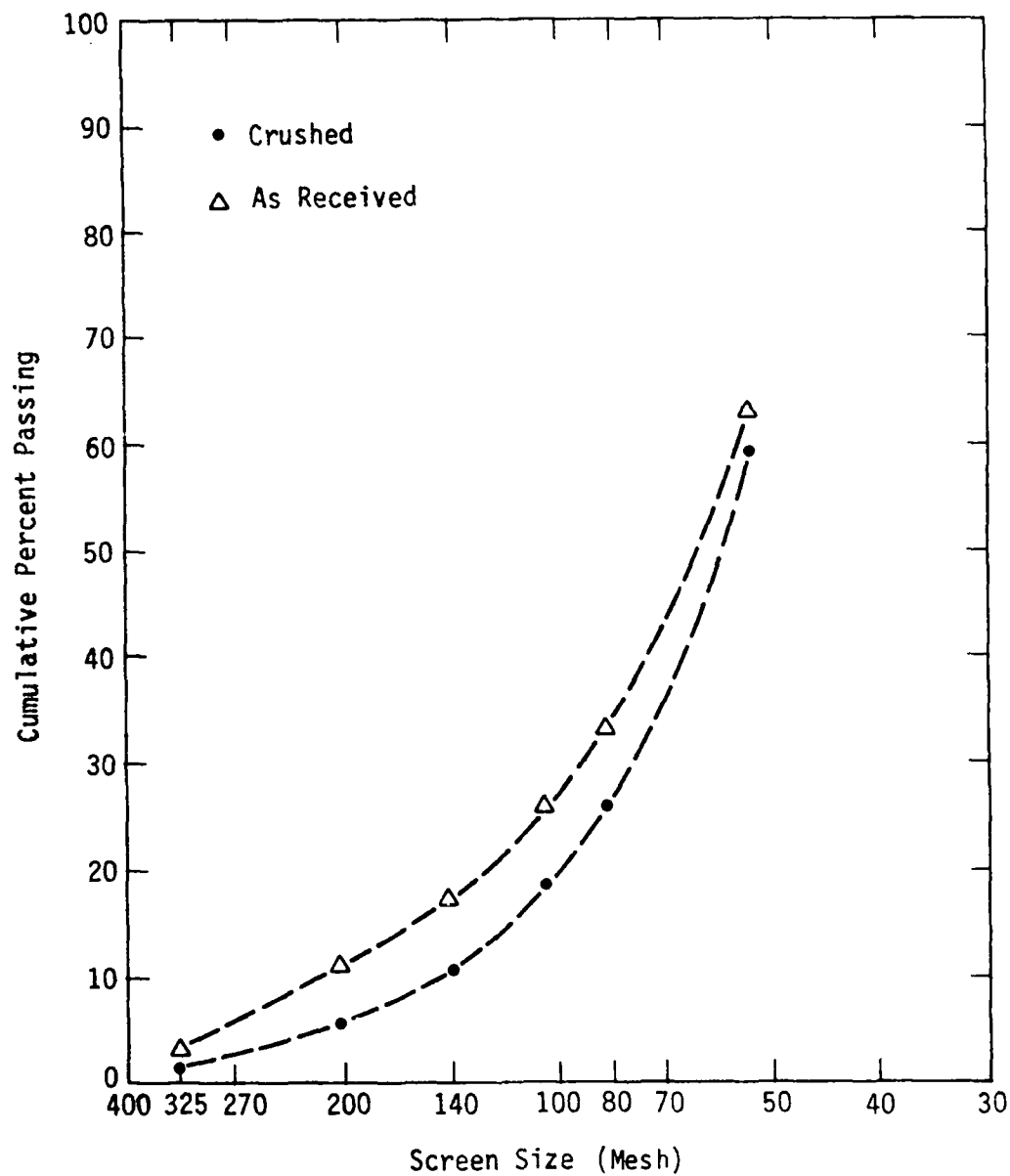


Figure 1. Screen Size Analysis On Sample 1, Cumulative Percent Passing.

TABLE 10. SCREEN SIZE ANALYSIS OF SAMPLE 4

Screen size, mesh	Retained on screen, %		Average of cumulative passing screen, %
	First test	Second test	
50	25.25	22.36	75.72
80	34.51	33.89	41.80
100	10.41	11.06	31.16
140	11.64	12.98	18.96
200	6.48	8.01	11.78
325	8.03	12.58	1.58
Pan	2.38	0.80	0.0

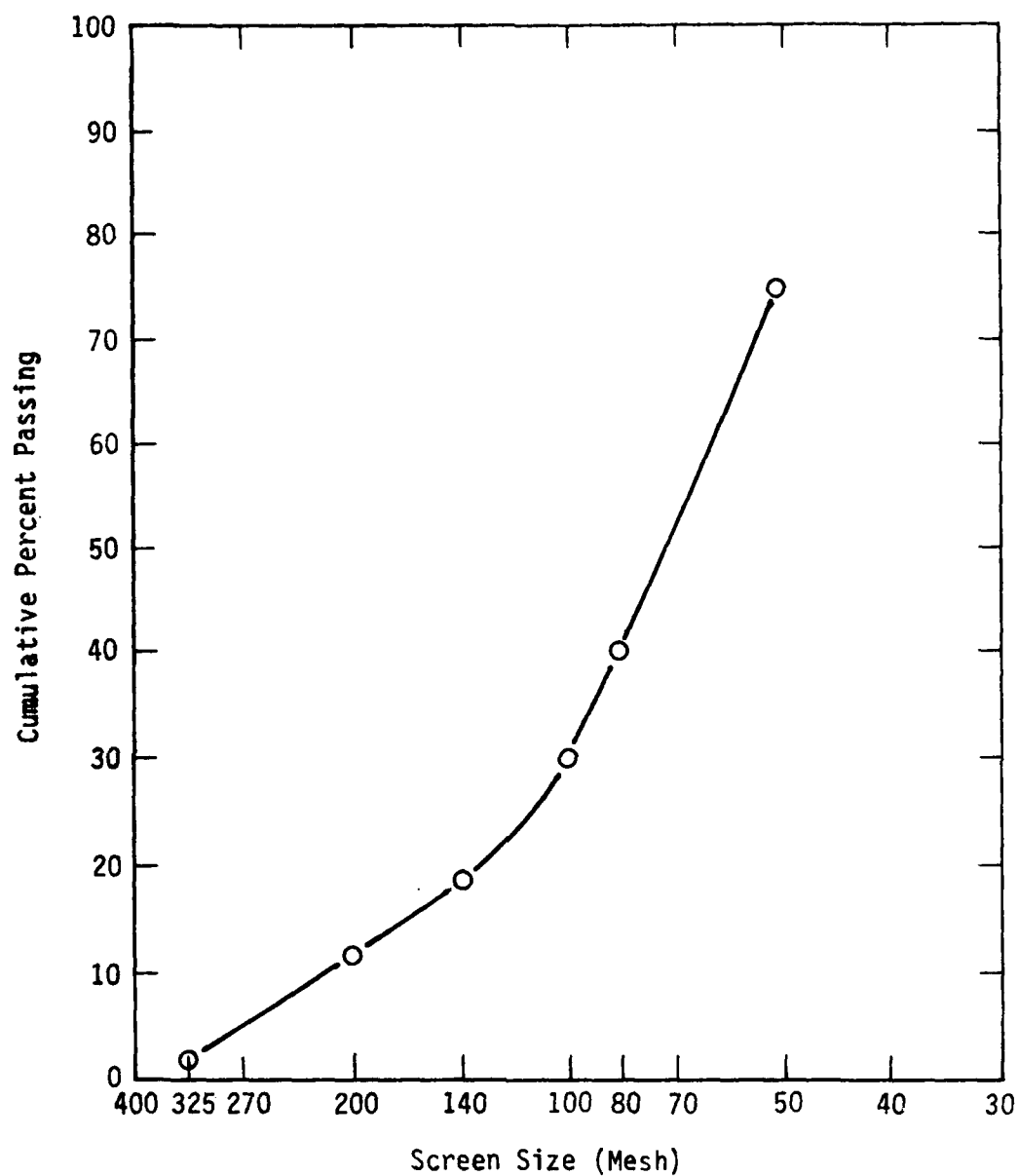


Figure 2. Screen Size Analysis On Sample 4, Cumulative Percent Passing, Weighted Average.

TABLE 11. SCREEN SIZE ANALYSIS OF SAMPLE 5

Screen size, mesh	First sample		Second sample		-200-Mesh fraction dried and rescreened	
	Retained, %	Cumulative passing, %	Retained, %	Cumulative passing, %	Retained, %	Cumulative passing, %
20	0.10	99.90	---	---	---	---
30	2.01	97.89	---	---	---	---
40	3.71	94.19	---	---	---	---
50	5.55	88.62	11.25	88.76	---	---
70			20.91	67.85	---	---
80	24.15	64.41	---	---	---	---
100	---	---	18.52	49.33	---	---
140	---	---	15.03	34.3	---	---
200	---	---	10.10	24.2	0.49	23.83
270	---	---	---	---	7.28	16.55
325	---	---	22.10	2.1	---	---
400	---	---	---	---	9.10	7.45
Pan	64.25	0.0	2.10	0.0	7.45	---

Sample 5 did not screen very successfully through openings smaller than 200 mesh. The -200,+325- and -325-mesh fractions were dried at 105 °C to 110 °C for 1 hour, and were separately rescreened. The improvement in screening ability is indicated by the 7.45 percent passing the 400-mesh screen, as opposed to the 2.1 percent which passed the larger, 325-mesh screen in the earlier trial.

The -325-mesh fraction lost 4.7 percent of its weight upon drying; the -200,+325-mesh fraction lost 5.03 percent. Most of this weight loss is

due to moisture content; the compressed air used in plastic media blasting contains some condensed water. However, a strong odor of formaldehyde did build up in the drying oven when the material was heated. The weight losses in drying have been arbitrarily added back to the data reported, to be consistent with the original screening, which was done without any drying.

Bag 6, a sample collected from the F-4 stripping area primary waste bins, on 18 November 1986, was screened to obtain the distribution for a more recent sample. The results of that screening, presented in Table 12, showed the presence of a somewhat larger amount of +50-mesh material than was found for Sample 5 (17 percent as compared with 11 percent). This is indicative of the variation encountered, owing to overflow through the shrouds in the F-4 blasting facility filter unit.

TABLE 12. SCREEN SIZE ANALYSIS OF BAG 6

Screen size	Retained, %	Cumulative passing, %
30	4.73	95.3
30	4.73	95.3
50	12.52	82.8
60	3.58	79.2
70	8.86	70.3
80	8.05	62.3
100	12.49	49.8
140	14.43	35.3
200	9.29	26.0
270	8.34	17.7
400	7.62	10.1
Pan	9.84	0.0

2. Filter Cake

An additional waste stream, other than the primary waste from the vibrating 50-mesh screen, is present at the Hill AFB F-4 paint-stripping facility. After the collected media and paint dust are drawn into the Bin Vent unit, following blasting, most of the material falls directly onto the screen. The air which conveys this waste to the unit is then drawn through filter cartridges and into the induced draft fan, and a dust cake builds up on the filter. When the pressure drop reaches a set point around 3 inches of water, a jet of compressed air within the filters blasts the cake loose and it drops directly on to the screen, which was a 50-mesh screen at the time the samples for this project were collected.

The filter cake is primarily very fine dust. If a major portion of the leachable material resides in this fraction, it would be desirable to install a system to direct the filter cake to a separate collector, rather than to mix it with the rest of the disposable residue.

Waste Sample 2 obtained from Hill AFB appears to be mostly filter cake. This sample is 97.3 percent smaller than 200 mesh, and is very high in all three elements of interest: Cd, Cr and Pb. It is physically difficult to obtain a representative sample of true filter cake, separate from the remainder of the waste, because of the design of the dust collecting system.

A 2-gram sample of Sample 2 "filter cake" was classified on very fine screens by ATM Corporation, Sonic Sifters Division, Milwaukee, Wisconsin. There is a fairly flat distribution of material from 30 through 5 micrometers. The result of this screen size analysis of Sample 2 are presented in Table 13 and Figure 3.

TABLE 13. SCREEN SIZE ANALYSIS OF SAMPLE 2

Screen size, μm ^a	Retained, %	Cumulative passing, %	Normalized log size ^b	Delta log size	% retained divided by delta
75	3.7	96.3	6.68		
45	12.6	83.7	5.42	1.26	10.0
30	14.5	69.2	4.42	1.0	14.5
20	17.6	51.6	3.42	1.0	17.6
15	12.7	38.9	2.71	0.71	17.9
10	17.1	21.8	1.71	1.0	17.1
5	11.6	10.2	0.0	1.71	6.8
Pan	10.2				

^aThe screen sizes 75 and 45 μm correspond to 200 and 325 mesh. The screen sizes of 38 μm have openings smaller than the smallest U. S. Standard Sieve size of 400 mesh.

^bSeveral size ratios are (1.5:1); therefore, the normalized distance, $[\text{Log}(\text{size}) - \text{Log}(5)]/\log 1.5$, gives one unit spacing between those sizes.

The equipment manufactured by ATM Corporation will sift only about 2 pounds per hour of material similar to the fine PMR waste dust, at a purchase price of \$8000.

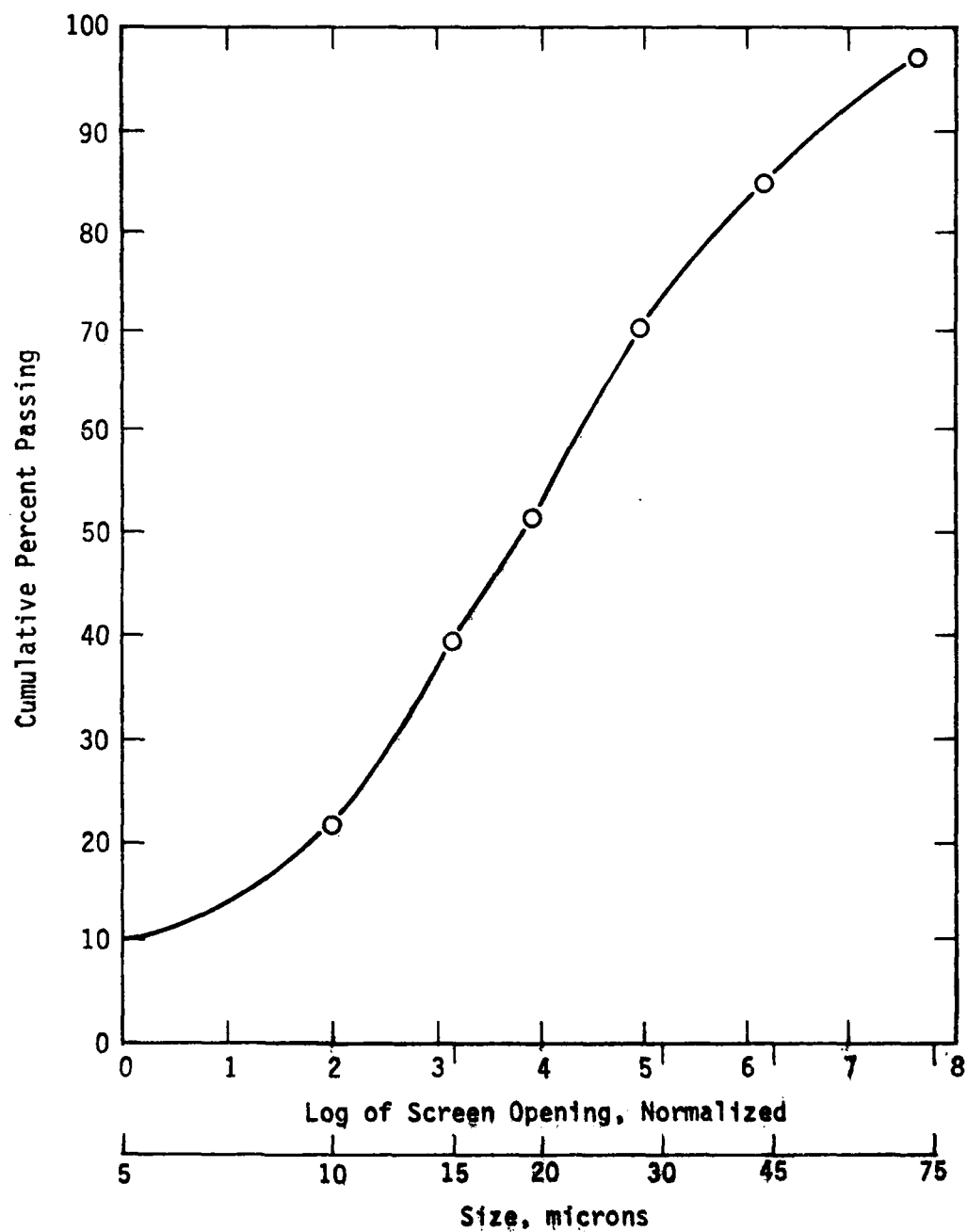


Figure 3. Screen Size Analysis On Sample 2, Cumulative Percent Passing, Weighted Average.

F. METAL ANALYSES ON PMB WASTE

1. Sample 1

EP Toxicity Test results for Sample 1, as received, are presented in Table 14. EP Toxicity Tests were also performed on different size fractions of Sample 1. The +50-mesh fraction was well within EPA limits; the -100-mesh fraction failed for chromium and cadmium. Lead was very low, and barium was present, although at much lower than required limits. EPA regulations require a statistical analysis for any determination showing a concentration greater than 80 percent of the limit. These results indicate that fractionation could separate PMB wastes into hazardous and nonhazardous components.

TABLE 14. EP TOXICITY TEST RESULTS FOR SAMPLE 1

Element	Concentration, mg/L					
	Allowed	Sample as received	+50 Mesh ^a		-100 Mesh ^b	
			Lab JE	Lab BU	Lab JE	Lab BU
As	5.0	<0.05	--	--	--	--
Ba	100.	0.51	1.05	<1.0	0.92	<1.0
Cd	1.0	0.32	0.19	0.12	1.0	0.92
Cr	5.0	10.06 ^c	0.80	1.30	19.0	29.4
Pb	5.0	<0.05	<0.05	<0.05	0.05	<0.05
Hg	0.2	0.002	--	--	--	--
Se	1.0	<0.01	--	--	--	--
Ag	5.0	<0.05	--	--	--	--

^a36.6% of total.

^b25.7% of total.

^cAverage for two determinations.

2. Sample 2

Sample 2 was divided into four equivalent portions of 3 pounds each by passing it through a 2:1 laboratory riffler twice. One of these portions was also split twice at 2:1, for a 16:1 final split. All subsequent testing of this material was done on samples taken from either a 4:1 bag or a 16:1 bag of material.

EP Toxicity Tests were performed on this material by two laboratories. The chromium results (Table 15) are in fairly good agreement, considering the erratic results which were noted in Section V and in Appendix B. Both chromium and cadmium concentrations are very high compared to results obtained for a more representative waste sample, such as Sample 1. Since Sample 2 contains a large percentage of fines, these results again indicate that contaminant concentrations are largest for small particle size.

Total metals were also determined, and the results were used to calculate the EP Toxicity Test values which would have been observed were all of the metal removed during the extraction (Table 15). The predicted (for 100 percent extraction) and actual results are similar only for cadmium. It appears that for Sample 2, extraction in the EP Toxicity Tests removed approximately 20 percent of the available chromium, 50 percent of the cadmium, and only very small percentages of the lead and barium. Sufficient barium and lead were present in Sample 2 to cause it to fail the EP Toxicity Test for these two elements if they were effectively extracted.

Though lead rarely appears at high levels when the EP Toxicity procedure is performed on the PMB waste, the total amounts found are not unexpected. Lead was used in the now discontinued lacquer top coats of paint, and many older aircraft have not yet been repainted with the new polymer coatings. Lead is also used in the light and dark green polyester formulations now being used at Hill AFB. Barium can be present because of the use of Barytes (barium sulfate) as a filler in the paint vehicle.

TABLE 15. METAL ANALYSES FOR SAMPLE 2

Element	Total metals, ppm	Expected EP Toxicity values if total extracted	EP Toxicity values, mg/L	
			Lab JE	Lab WA
Pb	1400	70	<.05	0.4
Cr	2500	125	24.89	29.3
Cd	600	30	18.0	12.7
Ba	2500	125	0.62	--

3. Sample 5

From the screen size analysis results, Sample 5 appears to be the most representative PMB waste collected. This sample was screened into eight fractions, which were separately analyzed by the EP Toxicity procedure. Identical samples of extracted liquid from each fraction were sent to each of three laboratories (HU, WA, JE) for analysis. This study was performed to determine the distribution of chromium and cadmium in the PMB waste. The grains of plastic media are not reduced completely to during use. They are gradually worn down such that a large part of the waste material is between 50 and 200 mesh. Earlier work indicated that the major portion of the paint would be found in the finest sizes of waste material. The results of the analyses by laboratory and by fraction are presented in Appendix Table B-1.

A major difficulty was the large variation among the laboratories, and the erratic results within each laboratory. As discussed in Appendix B, analysis of the variance of the results showed that it was unlikely that laboratory JE was consistently obtaining the same measurements as the other two laboratories. This laboratory was usually 30 percent lower than the other laboratories. Although lower readings would have helped justify the premise of the test, the higher readings from laboratories WA and HU are used to obtain the chromium averages given in Table 16 because they agree closely with each other and because analysis of a known standard indicated that their results were more reliable (Table 3). Lead results are not reported in Table 16, because, in all cases, the EP Toxicity value determined for lead was well below the limit of 5 mg/L.

The values in Table 16 for composites of several fractions are generated by calculating the fractional effect of the EP Toxicity readings on the average EP Toxicity value for a group of fractions. Each individual EP Toxicity Test value is multiplied by the weight of the fraction. The average EP Toxicity Test value for combined fractions is the sum of the weighted EP values divided by the sum of the weights of the fractions included.

Sample 5 was very high in EP Toxicity cadmium for the composite sample. Cadmium EP Toxicity values for PMB waste seldom exceed 1.5 mg/L. Although there is an obvious differentiation of hazardous material between the fine and coarse sizes, only the composite of the top 32 percent (larger than 70 mesh) meets the limit for chromium, and then by only a small margin. The top 75 percent of the dust does meet the 1.0 mg/L limit for cadmium by a small margin, because of the very sharp differentiation between the fine and coarse sizes, and in spite of the high composite value, 2.95.

TABLE 16. AVERAGE AND CUMULATIVE EP TOXICITY RESULTS FOR SAMPLE 5

Fraction	Fraction of total sample	EP Toxicity Test values, mg/L			
		Cadmium		Chromium	
		Average ^a	Weighted	Average ^a	Weighted
+50	0.1125	0.375	0.04219	1.1	0.12375
-50,+70	0.2091	0.6	0.12546	6.9	1.44279
-70,+100	0.1852	0.6	0.11112	7.05	1.30566
-100,+140	0.1503	1.1	0.16533	20.5	3.08115
-140,+200	0.1049	1.1	0.11539	25.25	2.64873
-200,+270	0.0728	16.45	1.19756	37.25	2.7118
-270,+400	0.0910	2.865	0.26072	28.0	2.548
-400	0.0745	12.45	0.92753	37.5	2.79375
Total Composite Sample			2.95		16.66
+200 Mesh Only (76.17%)			0.73 ^b		11.29
-200 Mesh Only (23.83%)			10.01		33.80
+100 Mesh Only (50.68%)			0.55		5.67
-100 Mesh Only (49.35%)			5.40		27.95

^aAverage of data from labs WA and HU only, for cadmium in fractions of -200,+270 and smaller and for all fractions of chromium. Laboratory JE results are not included.

^bThe following shows an example calculation for the cadmium EP Toxicity result expected for a composite of fractions of +200 mesh and larger. The fraction of material larger than 200 mesh is 0.7617 (76.17%). The EP Toxicity value for this fraction is equal to the sum of the weighted values for fractions from +50 mesh to -140,+200 mesh divided by 0.7617.

It is only 90 percent likely that there is a statistically significant difference between the chromium levels of the extracts of the five finest fractions. The random variation between the cadmium extracts appears to be even worse, but it could be argued that this contaminant appears as very fine dust in the -400-mesh fraction and as small flakes in the -200,+270-mesh fraction, thus, missing the -270,+400-mesh cut. Insufficient data are available to make a definite determination of this.

4. Bag 6

Bag 6 material was collected from the primary waste bins for F-4 stripping 18 November 1986. The material was carefully sieved and the fractions obtained were analyzed for metal content. The results in Table 17 indicate that the metal contaminants are concentrated in the finer material; however, the results also show that screening does not efficiently separate the contaminated and uncontaminated fractions. For Bag 6, screening gives only a small percentage (between 18 and 32 percent) that will pass the EP Toxicity Test.

TABLE 17. METAL ANALYSES ON SCREENED FRACTIONS OF BAG 6 MATERIAL

Fraction	Percentage of total	Total metals, ppm			EP Toxicity Test, mg/L		
		Cd	Cr	Pb	Cd	Cr	Pb
unscreened	--	152	1700	790	1.70	28.1	<0.2
+50	17.7	28	80	60	0.23	1.5	<0.2
50 X 100	32.1	34	700	420	0.40	13	<0.2
100 X 200	23.4	52	1900	1020	1.07	52	<0.2
200 X 400	13.9	162	3200	1320	3.71	80	<0.2
-400	12.3	770	2720	1260	6.9	68	<0.2

5. Filter Medium

The filter medium used to clean the exhaust air was analyzed at Hill AFB, and reported by the Chief of the Chemical Laboratory, Maintenance Directorate. Two used filter units were supplied for analysis. One, designated "clean," had excess dust blown off with a compressed air hose. The other was analyzed as is, including the amount of dust present when it was removed from the filter house. The results are presented in Table 18.

The higher EP Toxicity value for chromium in the cleaned filter medium compared to its as-removed condition may indicate that some of the chromate pigment particles are fine enough to become lodged in the micron-sized pores of the filter material, and that these fine particles are more soluble than the chromate pigment in the filter cake dust.

The larger amount of cadmium in the as-removed sample, and the higher EP Toxicity value indicate that the cadmium particles in the dust are too large to get into the filter pores.

The value of cadmium extracted in the EP Toxicity test is much less than the total amount present. The total cadmium contents of 900 and 400 ppm for the as-removed and clean-filter media, respectively, would appear as 45 and 20 milligrams per liter if all of the cadmium came out in the EP Toxicity test. Cadmium is above hydrogen in the electromotive series, but it does not appear to dissolve completely in either dilute acetic acid or in 10 percent HCl.

TABLE 18. EP TOXICITY TEST AND TOTAL METALS FOR FILTER MEDIUM

Element	Total metal, ppm		EP Toxicity value, mg/L	
	As-removed	Clean	As-removed	Clean
Lead	---	--	<.01	<0.1
Chromium (total)	240	170	2.9	14.0
Cadmium	900	400	3.2	0.2
Chromium(VI)	---	---	0.7	12.7

G. TREATMENT AND DISPOSAL TECHNIQUES

The most desirable technology for disposal would reduce the hazardous component of the waste dust to a small fraction of the total. This could be done if the paint solids component could be extracted from the remainder of the PMB waste for separate disposal. Physical separation could include specific gravity separation from an air stream by use of inertial impactor or cyclone type equipment, or float/sink separation in a liquid phase. Chemical treatment of the dust to remove some of the hazardous materials, followed by water treatment to separate a small amount of sludge could also reduce the volume of hazardous waste.

Other techniques include incineration of the entire waste dust production, with excess or deficient air, and subsequent disposal of the ash or char product. Encapsulation of the waste, or of the hazardous component, using a material resistant to water leaching would make the entire waste volume nonhazardous under RCRA.

1. Incineration

When several waste streams go to an incinerator, a permit must be processed completely for each waste stream. These permits include a determination of operating procedures, training of operator personnel, and methods of continuous monitoring of operating conditions, including CO/CO₂ ratio and other stack gas parameters. The procedure is complex and time-consuming. Adding another waste stream to an existing hazardous waste incinerator would be a major modification, and would require public notice and hearings with requirement for public comment.

Controls would be necessary to limit the emission of lead, chromium, and cadmium although standards have not yet been set. Particulates containing these metals can be controlled by a baghouse, preceded by a flue gas cooler to bring the temperature to around 160 °C. Serious problems have occurred in some incinerators with destruction/removal efficiencies when some types of plastics are added. This is probably caused when the plastic melts before charring.

Heat recovery from incineration of waste media was originally thought to be a consideration in the design of a process to mitigate the solid waste problem in plastic media blasting. The low energy costs at Hill AFB, however, make heat recovery uneconomical. At 11.6 J/g (5000 Btu/lb) and about 748 kilograms (1650 pounds) of waste per F-4 aircraft, approximately 8.69 gigajoules (8.25 million Btu) per aircraft will be generated. Hill AFB is paying \$3.25 per million Btu for natural gas. Thus the total value of heat from the waste from one F-4 aircraft is only \$26.80. The steam plant on Hill AFB has backup oil capability. At a heating value of 41.2 MJ/L (148,000 Btu/gal) for Number 2 oil, the PMB waste from one F-4 aircraft is equivalent to 212 liters (56 gallons) of oil, costing about \$40. If two aircraft per week are stripped, the value of the heat from PMB waste would be \$2800 to \$4200 per year. Considering the cost of incineration equipment, the payout time is too long to be an economic benefit.

The thermal decomposition properties of the waste were examined by heating small samples in a muffle furnace. At 288 °C, the material is converted to a yellowish powder, and does not melt. At 950 °C, in the absence of air, the material chars to give a graphite-like material and combustible vapors are evolved. When the fine fractions from PMB waste Sample 5 were dried in a small oven at 105 °C to 115 °C, an acrid-smelling vapor, believed to be formaldehyde, was observed. The fairly high water content of the fines could be due to moisture in the blasting air or to water given off and trapped in the condensation polymerization.

a. Glass Furnace

Several "high tech" incineration systems were investigated. The first one was really designed for incineration of toxic wastes which have a 99.99 percent removal requirement. It is a modified glass furnace designed by Penberthy Electromelt, Seattle, Washington. These units can be designed for through-puts of 220 to 22,000 kg/hr (100 to 10,000 lb/hr). Most of the heat required to maintain operating temperature is supplied electrically. Due to a very high thermal inertia, the 661 kg/hr (300 lb/hr) unit, the smallest practical size, takes 30 hours to reach the operating temperature. For incineration of wet material or substances with zero heat of combustion, the energy input is 300 to 350 kilowatts. When processing materials with high heats of combustion, this only drops to 175 kilowatts. The installed cost of the 661 kg/hr unit is \$1.4 to \$1.6 million. The high operating temperature of 1093 °C (2200 °F) causes rapid reaction of any organic material charged, and excess air is not needed.

Some of the larger units have a rotary kiln at the front to increase the flow-through of waste by predrying and partial burning. At the back, dry limestone towers can be added to remove any hydrogen chloride formed. However, this is not a problem with either melamine formaldehyde or urea formaldehyde resins, which contain no chlorine. Wet scrubbers followed by demisters are added to remove any particulate which leaves the furnace.

The major portion of the ash is captured in the molten glass on the hearth of the furnace and is periodically tapped off.

Though glass furnaces are excellent for handling highly hazardous wastes, their use is not justified solely for disposal of PMB wastes due to the high capital equipment costs. PMB wastes are regulated owing to their inorganic contents, rather than to organic contaminants. Glass furnaces are designed for effective destruction of organics.

b. Circulating Bed

A different type of incinerator burns material in an expanded, fluidized bed. GA Technologies was contacted about their moving bed incinerator. A GA Technologies demonstration unit has a capacity of 661 kg/hr (300 lb/hr) and is self-sustaining if the material has a heat of combustion of at least 18.6 kJ/g (8000 Btu/lb). Fuel can be burned to make up any additional heat which is needed.

The demonstration unit at GA Technologies has a 40.6-centimeter (16-inch) combustion column, and uses a gas flow space velocity of 4.6 to 6.1 m/s (15 to 20 ft/s). Larger units have capacities of up to 681 kg/hr (1500 lb/hr) of combustible material, with the same gas velocity. In operation, the bed of material is heated to 982 °C (1800 °F). As particles burn, the fines circulate and are collected in a cyclone and are returned to the bed. Fines which escape the cyclone are caught in a baghouse located in the bleed stream. Air pollution problems are stated to be minimal with this design.

The circulating bed combustor is engineered for a wide range of input material from liquid or sludge to granular solids. The heat of combustion may be negative, as in wet soil cleanup, or it may be as high as that of activated carbon, with a 14,000 Btu/lb heat of combustion. At 6000 to 12,000 Btu/lb, depending on the material properties or required

temperatures, the auxiliary gas burners can be turned off. Above 3000 Btu/lb, some heat may be removed from the combustor section.

If PMB waste having a heating value of 11.6 kJ/g (5000 Btu/lb) were burned at 136 kg/hr (300 lb/hr) in the small unit, about 316 MJ/hr (300,000 Btu/hr) of auxiliary fuel would be needed. However, up to 949 MJ/hr (900,000 Btu/hr) could be recovered in steam production by using some of the heat from the combustion section, and from a heat exchanger on the flue gas.

The circulating bed combustor operates in a range commonly referred to as a bubbling fluidized bed to an expanded bed. The residence time of gases is greater than 2 seconds. Because of the large holdup of solid material compared to the feed rate, the average residence time of solids is high, on the order of minutes. A sand bed is used to help disperse solid or liquid feed. The pressure drop in the system is from 73 to 86 Torr (39 to 46 inches of water). At 4.6 to 6.7 m/s (15 to 22 ft/s) space velocity in the 40.6-centimeter (16-inch) unit, 10 air horsepower is needed. This would be provided by a 20 hp motor, or greater.

The unit can be broken down and transported by truck to locations where hazardous waste exists provided the necessary gas and electric utilities are available.

The 136 kg/hr (300 lb/hr) unit, the smallest offered by GA Technologies, is too large to burn only the waste from the plastic media-blasting operation. The waste from one aircraft is only about 680 kilograms (1500 pounds). Even at a rate of two aircraft stripped per week, the dust produced in 3 months is about 19,000 kilograms (42,000 pounds), which could be disposed of in the 140 operating hours, approximately six 24-hour days.

GA Technologies performed extensive studies of PMB waste properties using differential thermal analysis and thermogravimetric analysis, assisted by gas chromatography of the gases evolved. Their sample was mostly smaller than 200 mesh (75 micrometers) and though they assumed that it consisted entirely of melamine resin, it may have been as much as one-third paint solids.

Thermogravimetric analysis showed weight losses of 5 percent at 100 °C, 75 percent at 350 °C, 90 percent at 470 °C, and 96 percent at 580 °C. Gas chromatography showed that water was evolved from 100 to 150 °C; ammonia, carbon-nitrogen compounds, and carbon dioxide, from 150 to 300 °C; methane and carbon monoxide, from 350 to 450 °C; and carbon monoxide alone, from 500 to 600 °C. The moisture content was 5 percent and the measured heat of combustion was 11.7 kJ/g (5040 BTU/lb). A dust explosion potential was found.

Circulating bed incinerators are useful for handling large volumes of waste; however, their use solely for PMB waste is not justified. This type of incinerator should be considered for handling the total regulated waste stream at a site.

c. Gasifier

The Sur-Lite Corporation of Santa Fe Springs, California has gasifiers similar in size to the GA Technologies circulating bed incinerators discussed above for incineration of waste. The combustion process is operated at 70 percent of stoichiometric air requirements, so that in addition to direct combustion, some of the carbon containing material cracks, and a char is produced. This is interesting in light of testing which showed chars passing the EP Toxicity test. The product gas has a low fuel value of about 4450 to 7450 J/m³ (120 to 200 BTU/ft³). This gas is burned in a Sur-Lite design burner, utilizing about 10 percent of the total heat output of the unit as propane. The propane flame is needed to keep the product gas ignited.

Some burners operate at 621 °C (1150 °F), with excess air. In one specific large installation, the burner operates at 760 to 870 °C (1400 to 1600 °F) and gases are cooled to 232 °C (450 °F) in a Dowtherm heat exchanger. (In this installation, the liquid is used in another heat exchanger to heat air for a cotton dryer.)

The fluidized bed operates at 760 to 870 °C (1400 to 1600 °F). Most of the sand remains in the column, while the fine ash flows out and is caught in primary and secondary cyclones. Like the GA Technologies incinerators, the thermal efficiency is 75 percent or more. The smallest unit operates from a 3 to 5 psi regenerative blower, and the much lower air requirement requires only a 1/3 horsepower motor. Since much of the process heat is in the sensible heat of the combustion products, the gas cannot be piped further than a few hundred feet for economic heat recovery.

The 1.5-million kJ/hr, 136 kg/hr, unit uses a 38-centimeter (15-inch) internal diameter column containing 771 kilograms (1700 pounds) of sand. The total amount of waste in the bed at any one time is usually 1 to 2 percent of this. The warm-up time is 4 to 5 hours from a stand by mode but 12 to 14 hours from a cold start. This long warm up time is due to the thermal inertia of the sand bed and the equipment.

The small unit is skid-mounted on a truck, and requires only piping up for operation. The price is \$110,000. Nine other units are available ranging in size up to 80 million Btu/hour capacity. The design and operation of this equipment are less complicated than that of GA Technology. However, installation instructions run to five pages, as do the ignition instructions. A skilled operator would be required to monitor the control systems during start-up and operation. Since this is another version of the circulating bed incinerator, the same conclusion holds for this process: It may be acceptable for high-volume wastes, but not for more limited streams.

2. Chemical Treatment

Sample 1 was extracted with 200 mL of a 10 percent aqueous solution of concentrated hydrochloric acid per 100 grams of material. The extracted solids were washed and a standard EP Toxicity Test was performed by Lab JE. The HCl extract was also analyzed. The results are in Table 19.

TABLE 19. SAMPLE 1 EXTRACTED WITH HYDROCHLORIC ACID

Element	Concentration, mg/L			
	Allowed	EP Toxicity Test, unextracted sample	HCl ^a extract	EP Toxicity Test, extracted sample
As	5.0	<0.05	1.0	<0.05
Ba	100.	0.51	1.051	18.69
Cd	1.0	0.32	2.4	0.9, 1.2
Cr	5.0	10.06	108.981	2.2, <0.05
Pb	5.0	<0.05	0.88	11.0, 15.2
Hg	0.2	0.002	2.912	0.001
Se	1.0	<0.01	<0.001	<.01
Ag	5.0	<0.05	0.008	<0.05

^aSince the amount of hydrochloric acid solution used was one-tenth the amount of extractant which would have been used for an EP Toxicity Test, the results have been divided by 10 to permit comparison with EP Toxicity results.

The 10 percent hydrochloric acid leach did not render the waste nonhazardous. The chromium removal was successful, since an EP Toxicity Test on the extracted material gave a chromium concentration lower than 5 mg/L. However, only some of the cadmium was removed by the hydrochloric acid; the EP Toxicity Test value for cadmium exceeded the 1 mg/L limit. Worse yet, not only did the hydrochloric acid leach remove only a small amount of the available lead, it solubilized the remainder so that the material failed the EP Toxicity Test for lead, whose concentration greatly exceeded its limit of 5 mg/L. (The same effect happened with the barium, but it still met its 100 mg/L limit.) Thus, lead and cadmium EP Toxicity values are made worse by hydrochloric acid extraction. Only the chromium value is improved. This suggests that hydrochloric acid extraction could be used for PMB wastes in which chromium is the only major metal contaminant.

The solids from the EP Toxicity extraction of Sample 2 (Table 15) were rinsed, and a second EP Toxicity extraction was performed. The liquids from both extractions were analyzed by Lab WA. The results are in Table 20. This time, the extracted lead remained low, although a large amount was present. The chromium was lowered to an acceptable level, as in the HCl leach. The cadmium continued its partial response to acid extraction, leaving about 7.7 to 13 mg/L of potentially extractable cadmium in the extracted solids (154 to 260 microgram per gram, dry basis, Table 15).

TABLE 20. CHEMICAL EXTRACTION OF SAMPLE 2

Element	EP Toxicity Extract, mg/L	
	First extraction	Second extraction
Pb	0.4	0.2
Cr	29.3	2.8
Cd	12.7	4.3

3. Charring

Heating of small quantities of either Sample 2 or unused media to 1382 °F (750 °C) and holding them there for at least 15 minutes gave a light-colored ash which appeared to be free of carbon or combustible organics. The moisture, ash, and volatile matter of Sample 2 were checked by methods similar to ASTM 3173-85, 3174-82, and 3175-82 (Reference 16). Volatile matter was measured as weight loss upon heating 7 minutes at 950 °C in a covered metal crucible. The remaining material is ash and carbon. The results of drying, charring, and ashing are in Table 21.

TABLE 21. MOISTURE, ASH CONTENT, VOLATILE MATTER^a

	New medium, ^a 20 X 40 mesh	Sample 2 ^a	Sample 5, -325 mesh	Sample 5, 200 X 325 mesh
Moisture, %	1.55	7.78	4.70	5.05
Ash, %, Dry Basis	1.94	10.50	--	--
Volatile Matter, %, Dry Basis	--	75.58	--	--
Carbon, by Difference, %, Dry Basis	--	13.92	--	--

^aAverages of three trials.

An EP Toxicity Test was performed on the char from Sample 2, the ash plus carbonized material remaining after volatile matter was driven off during 7 minutes at 950 °C in a metallic crucible with lid in place. The char easily passed the EP Toxicity Test. Charring of 114 grams of Sample 4 at 750 °C reduced the mass to 20.2 grams and also gave a material which passed the EP Toxicity Test. Heating at 500 °C for 15 minutes then at 750 °C for an additional 15 minutes converted Bag 6 material to a char which passed the EP Toxicity Test. The results for these experiments are given in Table 22. Insoluble forms of the metals or oxides are apparently created under the reducing conditions.

TABLE 22. EP TOXICITY TEST RESULTS FOR CHARS

Metal	EP Toxicity Test, mg/L					
	Sample 2		Sample 4		Bag 6	
	As received	Char	As received	Char	As received	Char
Pb	0.4	0.1	<0.2	<0.2	<0.2	0.30
Cr	29.3	0.3	18.0	<0.2	28.1	0.2
Cd	12.7	0.2	1.08	<0.5	1.70	0.05

Treatment by charring is not incineration; however, the permitting requirements would be at least as stringent. A major problem is the release of organic materials during the process. In incineration, organic volatiles are at least partially destroyed. Charring can be recommended only if the emissions are controlled and if the benefits are found to outweigh permitting difficulties. At present, charring is not recommended as a treatment method.

4. Encapsulation

a. Polyethylene

Petrothene polyethylene medium was obtained from U. S. Industrial Chemicals Division, National Distillers, Cincinnati, Ohio. Petrothene is a low density resin having a relatively high melt index of 22 grams per 10 minutes, as determined by ASTM D1238 (Reference 16). The polyethylene medium was melted at 205 to 232 °C (400 to 450 °F) in a muffle furnace, and portions of Sample 2, primarily filter cake, were stirred into the viscous melt. At these temperatures, the dust evolved a rotten fish odor typical of amines or amides, consistent with the plastic formulation. The melt assumed an opaque, black appearance, which may have been due to decomposition products or released pigments. A standard EP Toxicity Test was performed by Laboratory JE on a 2.8:1 mixture of polyethylene to waste dust, after dividing it into pieces passing a 0.9525-centimeter (3/8 inch) screen. The results, presented in Table 23, show that encapsulation in polyethylene gives a material which passes an EP Toxicity Test.

b. Polyurethane

A two-part polyurethane formulation used for runway patching, PERCOL S-100 from Arnco Chemical Co., Southgate, California, was used to encapsulate Sample 2 material in a ratio of 80:20, urethane to waste. An accelerator containing mercury was added to one of the polyurethane components. The polymerized plastic was broken up to pass a 0.9525-centimeter (3/8 inch) screen and EP Toxicity Tests were performed by Laboratory WA. The results in Table 23 show that polyurethane-encapsulated material easily passes EP Toxicity Testing.

The polyethylene encapsulation lowered the EP Toxicity levels better than did the polyurethane encapsulation; however, the concentrations are all well within allowable limits in both cases. Analysis shows an acceptable mercury level.

TABLE 23. EP TOXICITY TEST RESULTS FOR ENCAPSULATED SAMPLE 2 WASTE

Metal	EP Toxicity Test, mg/L					
	Untreated	Polyethylene	Polyurethane	Cement		
				0.582:1	0.304:1	Control
Pb	0.4	<0.05	<0.05	<0.05	<0.05	3.9
Cr	29.3	<0.05	0.75	28.8	12.	4.8
Cd	12.7	0.3	0.15	0.3	<0.01	0.1
Hg	--	---	0.003,0.004	---	<0.002	---

Although the plastic materials successfully encapsulated the PMB waste, the material cost may make such processes impractical. The price of 70 cents per pound of polyethylene, or about \$2.00 per pound of dust encapsulated cannot compete with the approximately 20 cents per pound of dust taken to a hazardous waste facility. If hazardous waste disposal costs were to rise significantly, encapsulation using plastic materials could become economically viable.

c. Cement

Components of an "acid-resistant" cement were received from GA Technologies, an incinerator designer. The components were used to prepare a formulation of 55.8 percent cement, 27.8 percent fly ash from coal-fired boilers, 12.6 percent bentonite clay, and 3.8 percent of "D-65," a proprietary resin. Waste dust was added to this formula in ratios of 0.304:1 and 0.582:1 and EP Toxicity Testing was performed by Laboratory JE. An EP Toxicity Test was also performed on a cement sample containing no waste by Laboratory WA. The results, in Table 23, show that encapsulation in this formulation does not permit passing of an EP Toxicity Test.

This cement is not actually acid-resistant, but the alkaline content is sufficient to neutralize all of the acetic acid which can be added in a standard EP Toxicity Test. Some metal ions, lead for example, may be soluble in acetate solution at higher pH values, so the results of the extraction procedure could not be predicted. The Pb and Cr values for pure cement are inconsistent with the results for cement plus waste dust.

Since Laboratory WA has given reliable analyses, the high lead and chromium concentrations for the cement blank are probably correct. Apparently, the cement formulation itself gives high EP Toxicity Test values. If the lead and chromium are in very soluble forms, the minimum amount in the cement in parts per million is calculated by taking 20 times the EP Toxicity reading. This calculation gives 78 and 96 ppm, respectively, for the minimum lead and chromium contents of the cement.

Conservation Services, Inc., Denver, Colorado, encapsulated some Bag 6 PMB waste with cement from kiln dust. The EP toxicity results for this material indicate an improvement in extractable metals; however, the value for chromium in a 50:50 cement/waste mixture is barely below the maximum allowed (Table 24). Subsequent encapsulations, using a Portland cement, are discussed later in this report.

TABLE 24. EP TOXICITY TEST RESULTS FOR CEMENT-ENCAPSULATED BAG 6 MATERIAL

Sample	EP Toxicity Test, mg/L		
	Cd	Cr	Pb
No encapsulation	1.70	28.1	<0.2
50:50 kiln dust/waste	<0.03	4.3	0.39

5. Density Separation

Sample 2 was determined to have a true specific gravity of 1.42 by weighing a portion in a known amount of water. An aliquot of Sample 2 was stirred into a solution of ferric chloride having a density of 1.42 g/mL. After 8 hours, the waste had separated into two fractions, one of which sank to the bottom of the container, the other of which floated. Initially, air trapped on some of the particulate floated some of the material, but eventually an air-free float layer was obtained. Material pipetted from the float and sink layers was analyzed for total lead, chromium, and cadmium (Table 25). Little difference is noticeable except for cadmium. Since the density of this metal is 8.642 g/mL, most of the metallic form should be at the bottom. However, since chromium is present mainly as part of the paint vehicle, whose density is very close to that of the plastic, separation by density will be difficult.

A separation was also attempted on Sample 4 using a 1.5 g/mL potassium iodide solution. In this case, the float fraction exhibited a significant decrease in total metals. These results are also presented in Table 25.

An attempt to use water settling on Bag 6 material failed to give any significant separation of hazardous and nonhazardous components. In this case the total metal contents for the top and bottom fractions were, respectively, 75 ppm and 66 ppm for cadmium, 1580 ppm and 1340 ppm for chromium, and 910 ppm and 1000 ppm for lead.

Separations using carbon tetrachloride were exceedingly promising. A dried sample of 100 X 140 fraction of Sample 5 was air elutriated for 1.5 hours and then stirred with carbon tetrachloride. About 94 percent of the material floated. The sink fraction contained most of the metals (Table 25). Similar separations well performed on a 50 by 60 fraction and a -60-mesh fraction of some F-4 aircraft PMB waste, screened by Rotex. Again, a very good depletion of metals was obtained in the float fraction.

A separation was attempted with a less toxic liquid - CFC 113 ($\text{CF}_2\text{ClCFCl}_2$). A 39.2-gram sample of Bag 6 was stirred into CFC 113 to give three layers - 9.35 grams in the float, 5.29 grams in the middle, and 19.19 grams in the sink. The analyses showed little separation; however, this may be due to the large amount of sink obtained. Other chlorofluorocarbons or CFC mixtures could give acceptable separations. For some unknown reason, in this separation, the more contaminated material was at the top.

6. Recycle Ratio Adjustment

In the F-4 stripping facility, the used blasting medium is screened following each use, and particles larger in size than 50 mesh (the value in use at the time of the present study) are returned for reuse. The fines are discarded as waste. On an average, blasting media are recycled 10 times before discard (93 percent recycle). If the ratio of waste to recycled material were increased during each cycle so that the average number of recycles were increased, the contaminant concentration would be lowered. The contaminants could be reduced to the point that the waste would pass the EP Toxicity Test. The recycle ratio can be adjusted by using a screen with a larger opening.

Decreasing the recycle would have three benefits: The waste could be made nonhazardous by a process requiring no permitting (since no external treatment is required), the blasting efficiency would be increased because of the decrease in finer material, and the dust concentration in the work area would be reduced. A major drawback, however, exists. The total amount of waste and the amount of new media required would increase. The increase in total waste is contrary to a desire for waste minimization.

Tests performed at Hill AFB, as part of another study, show that a large expenditure for new media would be required to obtain the needed reduction in contaminant concentration. Nevertheless, the use of recycle ratio adjustment must be considered further in view of its ability to give a nonregulated waste, increased blasting efficiency, and lower dust levels.

TABLE 25. METAL ION ANALYSES ON DENSITY-SEPARATED FRACTIONS^a

Fraction, % of total	Total metals, ppm			EP Toxicity Test, mg/L		
	Pb	Cd	Cr	Pb	Cd	Cr
Sample 2 in Ferric Chloride Solution						
float, --	400	200	380	--	--	--
sink, --	350	608	434	--	--	--
Sample 4 in Potassium Iodide Solution						
input	590	67	625	<0.2	1.08	18.0
float, 82%	230	25	150	<0.2	0.38	0.5
sink, 18%	1300	67	720	--	--	--
Sample 5 in Carbon Tetrachloride						
input	1400	60	1200	0.14	0.006	0.12
float, 94%	140	40	140	0.014	0.004	0.014
sink, 6%	17200	400	17100	1.72	0.040	1.71
Rotex Screened 50 X 60 Mesh in Carbon Tetrachloride						
float, --	--	22	148	--	--	--
sink, --	--	180	6290	--	--	--
Rotex Screened -60 Mesh in Carbon Tetrachloride						
input	--	--	--	<0.5	1.20	23.8
float, --	--	30	314	--	--	--
sink, --	--	650	5550	--	--	--
Bag 6 in CFC 113						
input	790	152	1700	<0.2	1.70	28.1
float, 28%	1390	248	2430	<0.5	1.97	64
middle, 16%	885	131	1480	<0.5	1.00	23
sink, 57%	660	191	1190	<0.5	1.04	20.5

^aDashes indicate that no measurements were performed.

H. FIELD TRIALS

1. Electrostatic Separation

Battelle, Columbus Division, in Columbus, Ohio, has developed an electrostatic separator for the separation of plastic blasting media and residue from metallic and other high density contaminants. Portions of Bag 6 material (primary waste from F-4 facility collected 18 November 1986) and Sample 2 (primary waste from F-4 facility, high in filter cake) were submitted for separation tests using this experimental electrostatic separator. Bag 13 material (PMB waste from Booth 412, Building 507, landing gears) and nonplastic blasting waste were also submitted for testing and the results of those tests are presented in Section VII. During operation, a rotating cylinder on the experimental electrostatic separator pulls material from a feed hopper. The cylinder is electrically grounded to eliminate any residual charge on the PMB waste particles. The PMB waste is then exposed to a high voltage gradient field created by a high-voltage positive electrode. A 0.159-centimeter (1/16 inch) diameter wire at a distance of approximately 2.54 centimeters (1 inch) was used for the Bag 6 and Sample 2 materials. Following exposure to the dc. electrostatic field, the PMB waste falls to either side of a gate. Material more attracted to the high-voltage field falls to one side of the gate and material less attracted falls to the other. A dc voltage of 17 kilovolts was found optimum. Higher voltages caused sparking between the wire and the rotating cylinder under high dust feed rates. Mechanical vibration was used to improve the flowing of the Sample 2 residue. Attempts were made to obtain a 50:50 split. Visual observations gave no indication of a successful separation. The fractions obtained in the electrostatic separator were analyzed and the results are presented in Table 26. The fractions are labeled "attracted more" and "attracted less" to denote attraction by electrostatic field.

TABLE 26. METAL ANALYSES OF FRACTIONS FROM ELECTROSTATIC SEPARATOR

Metal	Total metal, ppm				EP Toxicity Test, mg/L			
	Bag 6		Sample 2		Bag 6		Sample 2	
	Attracted more	less	Attracted more	less	Attracted more	less	Attracted more	less
Cd	115	100	690	690	1.0	2.0	14.7	15.5
Cr	790	2060	2160	2230	17.1	44.0	30.1	32.3
Pb	470	1110	1490	1480	<0.2	<0.2	<0.2	<0.2

The data indicate that erratic results may be expected for this method. A significant separation of contaminated and uncontaminated waste was obtained for Bag 6. On the other hand, little separation was achieved for Sample 2. Even where a significant separation was achieved, the fraction with a lowered metal content still failed to pass the EP Toxicity test. Electrostatic separation is not a promising treatment process for the waste from plastic media blasting of F-4 aircraft.

2. Aerodynamic Classification

Experiments discussed earlier have indicated that screening is unlikely to permit a practical and useful separation of hazardous and nonhazardous components. Particles of the two components differ little in size, and the separation by screening is not as complete as needed. Density separations could prove useful; however, the logistics and costs of this type of operation are drawbacks. Waste plastic particles and paint chips, which are believed to be chromium-free and chromium-bearing, respectively, have very similar sizes and densities; however, their shapes are likely to be very different. Thus, separations based on aerodynamic principles were evaluated.

Aerodynamic classification separates particles by size, based on the terminal velocity of a sphere, as expressed in Stoke's law,

$$v = \frac{2ga^2(d_1 - d_2)}{9\nu}$$

where a is the sphere radius, d_1 and d_2 are the densities of the particle and medium, respectively, and ν is the viscosity of the medium. The terminal velocity is the sphere velocity at which gravitational and frictional forces are equal. The Stokes-equivalent radius of a particle is the radius of a perfectly spherical and homogeneous sphere that has the same terminal velocity as that measured for the particle. The aerodynamic particle size depends on size, shape, surface texture, and homogeneity.

If successful, aerodynamic classification would offer several advantages. Classification is usually faster and more effective than mechanical screens. Aerodynamic classifiers are often less expensive in both initial investment and in operating costs. Also, many aerodynamic classifiers are adjustable, a feature allowing fine tuning. Of particular importance for the present case is the expected difference in Stokes-equivalent diameters for particles of the hazardous and nonhazardous components.

Air elutriation experiments were performed on 50- by 70-mesh and 100- by 140-mesh cuts of Sample 5. Portions of these fractions were placed in a 5.1-centimeter (2-inch) vertical glass tube and air was blown through them with a velocity adjusted to remove only the finest components. The fractions obtained were analyzed for total metals. The results, in Table 27, show that significant separation of contaminated fines and less-contaminated coarse material is obtained. Additional experiments were performed with Bag 6 material. A 60-gram portion of Bag 6 material was separated to give 23.82 grams of fines and 32.45 grams of bottom. Air elutriatic was also performed on 51.81 grams of 80 by 100 Bag 6 material to

TABLE 27. METAL ANALYSES OF AIR-ELUTRIATED FRACTIONS OF SAMPLE 5 AND BAG 6

Metal	Total metal concentration, ppm								EP Tox, mg/L	
	Sample 5				Bag 6				Bag 6	
	50 X 70		100 X 140		As-received		100 X 140		As-received	
	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse
Cd	519	35	716	57	336	48	62	42	2.74	0.35
Cr	1641	261	2034	1198	2400	800	4140	660	48.4	19.6
Pb	--	--	--	--	1070	388	1890	466	<0.2	<0.2

give 7.41 grams of fines and 42.70 grams of coarse. These results are also shown in Table 27 and again demonstrate a partial separation of a metal-containing fraction from a nonmetal containing fraction. Although partial separations are obtained, the results for Bag 6 show that efficient separation into nonhazardous and hazardous components is apparently not possible by air elutriation.

To determine whether separation based on particle shape could provide a solution, a 55-gallon drum of F-4 PMB waste was submitted to Fisher-Klosterman, Inc., Louisville, Kentucky, for aerodynamic classification on their EXL-12 Classifier. This equipment has an inlet volume of 653 L/s (1383 ft³/min) and a reverse air flow of 278 L/s (590 ft³/min). The EX Series Aerodynamic Classifier combines a high-efficiency cyclone and a fluid bed. In the cyclone section, which operates by centrifugal force, a vortex of particulate-bearing gases is generated. Heavier, denser particles are projected outward toward the walls, where they spiral downward to the classification section. The classification section

uses a stream of gas blown upward through the particles. As particles move down, they are restricted to a narrow space between the walls of the classifier and an internal cone. A reverse flow of gas from the lower section allows only the desired large particles to fall through the restriction. The reverse flow moves upward and carries smaller particles with it. An increasing percentage of heavy particles can be carried upward by increasing the velocity of gas flow. By regulating the reverse gas flow, one can adjust the aerodynamic size difference between coarse particles collected at the bottom and fine particles discharged at the top.

The classified material was sieved to determine percentages of particle sizes after classification. The size distribution of the bottom fraction, with a lowered chromium content, is compared with that of the input sample in Table 28. Elemental analyses of the input sample and of the sieved fractions of the bottoms are presented in Table 29. The classifier bottoms were approximately 75 percent of the total.

TABLE 28. SCREEN SIZE ANALYSIS OF AERODYNAMICALLY CLASSIFIED WASTE

Screen size	Retained on screen, %	
	Input	Classifier bottoms
40 mesh	12.57	24.26
70 mesh	37.78	47.46
pan	49.7	28.2

TABLE 29. METAL ANALYSES ON AERODYNAMICALLY CLASSIFIED WASTE

Fraction, %	Total metals, ppm		EP Toxicity Test, mg/L	
	Cd	Cr	Cd	Cr
Input	88	989	0.37	37
Bottoms, + 40 mesh	20	163	0.07	5
Bottoms, 40 X 70 mesh	18	329	0.07	16
Bottoms, -70 mesh	31	869	0.14	32

Though the bottom fraction of the aerodynamic classification does show a lower chromium content, the improvement is insufficient to warrant consideration of this process for waste treatment. In particular, all screened fractions from this process failed the EP Toxicity Test.

I. RANKINGS AND RECOMMENDATIONS

The rankings and recommendations for treatment methods for Phase I and II studies have been combined and are presented in Section VIII.

SECTION VII
PHASE II: OTHER BLASTING WASTE

A. SAMPLES COLLECTED

All blasting facilities at Hill AFB are listed in Table 30. Samples collected on 18 November 1986 from areas other than the F-4 stripping area (Building 223) are listed in Table 31. The sampled material included residue and initial material from blasting with plastic media, garnet, aluminum oxide, titanium oxide, walnut shell, glass beads, and ground apricot pits. Three types of material were collected: new media from shipping containers, partially recycled media from blasting booth floors, and waste from bins. It is very likely that much of the bin waste was a mixture of wastes from more than one process.

Wing-fold blasting using 30- by 40-mesh and 12- by 16-mesh Polyplus resin is accomplished in a blasting booth within Building 205. The 12- by 16-mesh resin is used as a makeup material as the plastic media particles wear down. Used media are not screened for recycling; size fractionation is accomplished by the booth itself, which acts as a settling chamber. Material which settles out is swept or shoveled into a screw conveyor in the floor, where it is conveyed to be reused. Very fine material which does not settle out rapidly is removed by sweeping air through the booth and collecting airborne material in filters. This combination of a floor auger and pneumatic transport of airborne fines is used as a recycling method for all blasting booths (but not blasting cabinets, which have no floor augers) except Building 223.

Building 505 contains two blasting booths. One booth uses 100-mesh garnet for cleaning landing gears; the other uses a 180-mesh mixture of aluminum and titanium oxides to clean gun parts. Waste production at this building is approximately 6000 to 9000 pounds per month.

Building 507 houses two blasting booths (#416 and #412) and two smaller blasting cabinets (#413 and #417). Booth #416 uses plastic media or walnut shell/plastic mixtures for stripping aluminum wheels. Like all other plastic media found at Hill AFB, the plastic media are U. S. Technology Corporation material. Booth #412 uses only black walnut shell. Cabinet #417 uses only glass beads. The two blast cabinets are very small producers of waste, which is trapped by integral dust collectors and is eventually deposited in the same bins used for the blasting booth wastes.

The Building 847 blast area uses a variety of media for stripping missile trailers: garnet, plastic (Polyplus), and apricot pits. The missile trailer blasting booth appears to be an integral part of the building; however it is isolated by concrete block walls. Although the rest of Building 847 is protected by an automatic sprinkler system, this system does not extend into the blast area.

TABLE 30. HILL AFB BLASTING FACILITIES

Building	Stripping operation
223	F-4 aircraft
505	gun parts and landing gears
507	landing gears, wheels
847	missile trailers
205	wing folds

TABLE 31. SAMPLES COLLECTED FROM AREAS OTHER THAN F-4 BLASTING FACILITY

Bag	Bldg.	Location	Material
8	505		new 100-mesh garnet
9	505		new 180-mesh aluminum oxide/titanium oxide mix
10	505		waste garnet
11	505		waste aluminum oxide/titanium oxide mix
12	505	floor	partially recycled garnet
13	507	Booth 412	PMB waste
14	507	Booth 416	waste plastic/walnut shell mix
15	507	Booth 416	partially recycled plastic/walnut shell mix
16	507	Cabnt 417	waste glass beads
17	847	floor	partially recycled garnet/plastic/apricot pit mix
18	847		waste garnet/plastic/apricot mix
19	205	floor	partially recycled plastic
20	205	bin	PMB waste

B. SCREEN SIZE ANALYSES

Screening analyses were performed on each major waste stream from the facilities sampled on 18 November 1986; the results are presented in Table 32. Glass bead waste was not analyzed because it is generated in very low amounts. The garnet blasting waste (Bag 10) consists largely of fines. More than 50 percent is -325 mesh. The PMB waste from wing fold blasting (Bag 20) contains a large amount of coarse material in comparison with the other material in Table 32; about 50 percent is +70 mesh. The size distribution for this sample, however, is not strikingly different from that observed for PMB waste from the F-4 blasting area.

TABLE 32. SCREEN SIZE ANALYSES ON WASTE FROM AREAS OTHER THAN F-4 AREA

Sieve mesh	Retained, %					
	Bag 10	Bag 11	Bag 13	Bag 14	Bag 18	Bag 20
50	0.05	0.04	0.12	13.31	17.07	32.63
70	0.09	0.13	1.94	7.56	8.32	17.03
100	0.66	0.17	9.22	8.70	12.97	17.64
140	5.95	0.77	20.39	13.22	15.04	14.11
200	15.42	20.14	13.96	19.02	18.84	8.82
230	5.44	14.17	32.04	17.03	7.33	2.16
270	16.31	35.98	8.98	9.40	12.80	2.81
325	5.15	4.77	5.76	4.09	1.98	0.80
400	13.31	8.46	5.64	8.61	2.07	0.92
Pan	40.02	15.41	1.94	9.01	2.93	2.85

C. METAL ANALYSES

Metal analyses were performed on each major waste stream. The results are presented in Table 33. All five wastes failed the EP Toxicity Test for cadmium, in some cases by large amounts. Only Bag 20 waste, from wing fold stripping, failed the EP Toxicity Test for chromium, although Bag 18 material from missile trailer stripping came close. In no case did a sample fail owing to extractable lead. The amounts of cadmium are surprisingly high for several wastes. The waste from wing fold stripping resembles that from F-4 blasting and both waste streams can probably be treated similarly.

TABLE 33. METAL ANALYSES ON WASTE FROM AREAS OTHER THAN F-4 STRIPPING AREA

Sample	Total metals, ppm			EP Toxicity Test, mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
Bag 10	906	102	28	45	<0.2	<0.2
Bag 11	510	50	36	28	<0.2	<0.2
Bag 13	5070	159	28	202	1.40	0.23
Bag 14	290	160	40	13.2	3.10	0.45
Bag 18	149	450	625	5.88	4.55	3.5
Bag 20	150	585	580	1.8	9.6	<0.2

D. TREATMENT AND DISPOSAL TECHNIQUES

1. Encapsulation

Bag 11 material (waste garnet from blasting of gun parts and landing gears) failed the EP Toxicity test only owing to cadmium (Table 33). Encapsulation in 50 percent by weight kiln-dust cement by Conservation Services, Inc., Denver, Colorado, gave material which passed the EP Toxicity Test (Table 34). The small increase in lead may be due to lead in the kiln dust itself.

Bag 20, PMB waste from wing-fold stripping, failed the EP toxicity tests owing to both cadmium and chromium; however, neither material was present in extremely large amounts (Table 33). Encapsulations were attempted by heating mixtures containing 15 percent acrylic thermoplastic. Mixtures were heated at 250 °C and 210 °C for 30 minutes. In both cases, the product charred somewhat and was slightly sticky. One sample was pressed in a pellet press while heating at 170 °C. The product was initially solid but fell apart during analysis. Heating at 250 °C and 210

°C gave material which passed the EP Toxicity Test for chromium; however, the material was worse for cadmium and lead (although it still passed for lead). The results (Table 34) indicated that heating increases the amount of extractable cadmium and lead. This was also seen in some low-temperature heating experiments discussed later in this report. Material was also encapsulated, using a mixture containing 10 percent epoxy resin cured for 2 hours at 75 °C. Again, this material failed the EP Toxicity Test for cadmium but it easily passed the chromium requirement (Table 34).

A large number of cement encapsulations were performed on Bag 20 material using portland cement, sand, rock aggregate, and PMB waste. The resulting encapsulated products all passed the EP Toxicity Test. The results indicated that aggregates containing up to 50 percent by weight of PMB waste should be able to pass an EP Toxicity test; however, no compositions containing this much residue were actually tested. As the residue increases, the strength of the encapsulated product decreases.

2. Electrostatic Separation

Separations of hazardous and nonhazardous components were attempted, using the Battelle electrostatic separator used earlier on waste from F-4 blasting. The results, presented in Table 35, show no significant difference in the two fractions obtained.

TABLE 34. METAL ION ANALYSES ON ENCAPSULATED WASTES

Process	Total metals, ppm			EP Toxicity, mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
Bag 10 Encapsulated in Kiln Dust Cement						
no encapsulation	906	102	28	45	<0.2	<0.2
encapsulated 50:50	--	--	--	<0.03	<0.2	0.30
Bag 20, Encapsulated with Acrylic or Epoxy Resin						
no encapsulation	150	585	580	1.8	9.6	<0.2
acrylic, 30 min at 250 °C	--	--	--	4.6	2.68	0.79
acrylic, 30 min at 210 °C	--	--	--	3.8	2.48	0.42
acrylic, pressed at 170 °C	--	--	--	1.5	7.60	0.10
epoxy, 2 hours at 75 °C	--	--	--	3.9	0.54	0.58
Bag 20, Cement Encapsulations ^a						
no encapsulation	150	585	580	1.8	9.6	<0.2
100/150/300/0 (no waste)	--	--	--	<0.1	0.05	<0.5
100/150/250/50 (63% water)	--	--	--	<0.1	0.28	<0.5
100/150/200/100 (50% water)	--	--	--	<0.1	0.55	<0.5
100/150/150/150 (42% water)	--	--	--	<0.1	0.90	<0.5
100/150/100/200 (40% water)	--	--	--	<0.1	1.00	<0.5
100/100/300/50 (58% water)	--	--	--	<0.1	0.35	<0.5
100/50/300/100 (43% water)	--	--	--	<0.1	0.50	<0.5
100/0/300/150 (37% water)	--	--	--	<0.1	1.25	<0.5
100/100/250/100 (46% water)	--	--	--	<0.1	0.65	<0.5
100/50/200/200 (37% water)	--	--	--	<0.1	1.40	<0.5

^aThe parts by weight of cement, sand, rock aggregate, and PMB waste are given. Thus "100/150/250/50" denotes 100 parts of cement, 150 parts of sand, 250 parts of aggregate, and 50 parts of waste. The percentages of water are based on the final wet mix.

TABLE 35. EP TOXICITY TESTS ON ELECTROSTATICALLY SEPARATED FRACTIONS^a

Metal	EP Toxicity Test, mg/L							
	Bag 11		Bag 13		Bag 14		Bag 18	
	Attracted more	less	Attracted more	less	Attracted more	less	Attracted more	less
Cd	28	30	180	210	3.5	4.0	4.1	3.2
Cr	<0.1	<0.1	1.21	1.39	0.88	1.36	<0.1	0.15
Pb	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.10	<0.1

^aThe fractions are labeled "more" and "less" to denote relative attraction to the charged plate.

3. Chemical Extraction

A portion of Bag 20 material was extracted for 2.5 days at 118 °F using the water and sufficient acetic acid to maintain the pH at 5.0 using the proportions specified in the EP Toxicity Test. Metal ion concentrations were determined for the leachate and total metals and a standard EP Toxicity Test was run on the solid. Total metals were then determined on the doubly extracted solid remaining from the EP Toxicity Test. The results are presented in Table 36. Leaching decreases extractable chromium; the extracted material easily passed the EP Toxicity Test for this metal. However, chemical extraction appears to adversely affect the EP Toxicity test for cadmium.

TABLE 36. EXTRACTION OF BAG 20 MATERIAL WITH WATER AND ACETIC ACID^a

Material	Total metals, ppm			EP Toxicity, mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
Untreated	150	585	580	1.8	9.6	<0.2
Extract	nd	nd	nd	2.8	8.9	<0.2
Singly Extracted Solid	81	470	520	3.3	0.8	1.1
Doubly Extracted Solid	59	525	720	nd	nd	nd

^a"nd" in table denotes "not determined."

4. Heat Treatment

Charring at 750 °C has been shown to significantly improve EP Toxicity results. To determine whether lower temperatures would do the same, portions of Bag 20 were heated for 30 minutes at temperatures ranging from 150 °C to 525 °C and EP Toxicity tests were run. The results in Table 37 show that heating in this range in general does not improve the EP Toxicity Test results and can harm them. Interestingly, heating causes extractable cadmium to initially increase and then decrease as the temperatures used increase. Extractable lead increases with increasing temperature.

TABLE 37. METAL ANALYSES ON HEAT-TREATED BAG 20 MATERIAL

Material	Total metals, ppm			EP Toxicity, mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
Untreated	150	585	580	1.8	9.6	<0.2
30 min at 150 °C	--	--	--	1.60	9.50	<0.2
30 min at 175 °C	--	--	--	2.74	8.36	<0.2
30 min at 200 °C	--	--	--	2.78	7.40	<0.2
30 min at 250 °C	--	--	--	4.84	2.49	0.62
30 min at 250 °C	--	--	--	5.90	2.70	0.53
30 min at 275 °C	--	--	--	5.30	3.05	0.80
30 min at 300 °C	--	--	--	5.30	4.40	2.00
30 min at 325-375 °C	--	--	--	3.90	3.95	4.10
30 min at 350 °C	--	--	--	2.80	0.18	1.30
30 min at 525 °C	--	--	--	1.85	4.20	3.20

SECTION VIII
WASTE TREATMENT TECHNOLOGIES

A. ANALYSIS AND RANKING OF TECHNOLOGIES

In this section, primary attention is directed toward F-4 stripping waste, recognizing that many techniques are also applicable to other waste streams. The following criteria were adopted for ranking of waste treatment technologies:

1. Application Factors
 - a. Ease of implementation
 - b. Ease of operation
 - c. Ability to fit into base routine
2. Economic Factors
 - a. Capital equipment costs
 - b. Operating costs
 - c. Resource recovery
3. Environmental Factors
 - a. Reduction of waste stream
 - b. Environmental impact
 - c. Regulatory compliance (ease of permitting)

Several of these criteria could be placed in more than one category. A decision was made, for example, to include "Ability to fit into base routine" under "Application Factors," rather than "Economic Factors." The current and projected quantities of residue have little impact on relative rankings of technologies. The current quantities are discussed in several

sections within this report. A recent decision to eliminate all, or nearly all, chemical paint stripping of aircraft makes it likely that the total waste stream will increase by a large factor, perhaps 20 times that of today. The analysis presented below is based on the above criteria.

1. Incineration - The initial and operating costs are very high; however, a suitable incinerator would handle many waste streams. Licensing is a long, drawn-out, difficult procedure. The major advantage of incineration is the large reduction in volume (approaching 98 percent) of hazardous waste. Most of the other processes considered here leave a significant hazardous residue, which would still have to be disposed of. All of the other processes require disposal (presumably landfill) of waste which has been made nonhazardous under RCRA. If regulatory changes were to occur, sites containing these wastes could require costly cleanup.

2. Chemical Treatment - The chemical extraction methods evaluated were successful for chromium but were ineffective for cadmium and lead, which often had increased EP Toxicity values following extraction. Although chemical treatment could prove useful for waste containing chromium only, a major drawback with aqueous extraction is the generation of liquid waste streams.

3. Charring - Heating PMB waste to high temperatures produces a char which easily passes the EP Toxicity Test. A major problem with this procedure is the presence of air emissions. It could be as difficult to license this technique as to license an incinerator.

4. Encapsulation - This low-cost procedure is easy to carry out and fits well into base routine. It could be implemented rapidly; however, permitting would be required. The major problem with this technique is that it increases the total mass of waste even while converting hazardous waste to nonhazardous waste.

5. Density separation - This technique can permit separation of hazardous waste into two components: hazardous and nonhazardous. Although the methodology is difficult and the equipment and operating costs could be high, flotation in a liquid could prove highly effective as indicated by the results using carbon tetrachloride. Chlorofluorocarbons, which have high volatilities and low toxicities, are good candidate liquids.

6. Recycle ratio adjustment - Decreasing the fraction of material which is recycled could possibly give a nonhazardous material. This is easily accomplished by changing the vibrating screen in the recycling unit to provide a larger mesh. A major difficulty with this procedure is that the waste is sufficiently variable that the results are likely to be erratic. Moreover, the raw material costs and overall waste volumes will increase.

7. Size separation - A major objective of the Phase II effort was to physically separate the wastes by particle size into regulated and nonregulated components. Although the contaminants are more highly concentrated in the fines, the studies reported here show that separation by size will not accomplish a significant reduction in hazardous waste volume.

Each of the above technologies has been rated according to the criteria shown earlier in this section. A "+, 0, -" rating system (from favorable to unfavorable) has been used. The results are shown below.

	Application			Economic			Environmental		
Criteria:	1	2	3	1	2	3	1	2	3
Incineration	-	0	+	-	0	0	+	+	-
Chemical Treatment	0	-	-	0	-	-	-	-	-
Charring	0	0	0	0	0	-	0	-	-
Encapsulation	+	+	0	+	+	0	-	0	0
Density Separation	+	-	0	0	0	0	+	0	0
Recycle Ratio	+	+	+	+	+	-	-	-	+
Size Separation	0	0	0	0	+	0	-	-	+

B. LIMITED-SCALE FIELD TEST

The evaluation shown above is somewhat qualitative. Moreover, two technologies which have relatively high rankings - size separation and recycle ratio - are not likely to function efficiently. At present, encapsulation is the only highly ranked technology which has been proven conclusively to provide effective treatment. A limited-scale field test of encapsulation with cement is proposed. This technique can be introduced rapidly and could be discontinued easily if another technology, such as incineration, were introduced. Since the F-4 PMB waste is highly variable, several days of operation are needed to ensure compliance. The following procedure would be used.

1. Consult with environmental authorities to obtain permit for field experimentation.
2. Select a time during which the F-4 stripping facility is in full operation.
3. Purchase portland cement and 55-gallon drums for disposal.
4. Mix cement, waste, and, as needed for strength, sand/aggregate in drums. Discard drums of the cured material intact.
5. Sample each drum and perform EP Toxicity Testing.
6. Determine costs based upon results.

This proposal does not address equipment selection and costs since equipment requirements (a cement mixer and empty drums) are minimal. Sufficient work could be accomplished in 2 days to determine problem areas. The approximate cost would be \$6000, including analyses of the encapsulated materials. The work does not have to be accomplished onsite since the treatment technology is not site-dependent. The wastes could be shipped to another location for this pilot study.

SECTION IX
PHASE III: FIRE RISK ANALYSIS

A. BACKGROUND

The Bureau of Mines has investigated the explosibility and ignitability of plastic blasting media (Reference 17). In that report, the following conclusions were made.

1. Recycled media in the range of 12 to 80 mesh will not explode.
2. Paint particles do not affect explosibility.
3. The largest particle size which exploded was 40-mesh Polyextra at 200 grams per cubic meter.
4. The lowest explosive concentration at 200 mesh was Polyextra at 45 grams per cubic meter.
5. The greatest dust explosion potential is in the baghouse.

The Bureau of Mines study showed that high-intensity explosions were possible but were unlikely, except in places where the dust concentrations were very large, such as the baghouse. Since this study did not address flammability of dust layers, such studies were made part of the present project.

B. LAYER IGNITION TEMPERATURES

1. Procedure

Layer ignition temperature tests were conducted to establish the minimum temperature of a hot surface that will result in the ignition of a

layer of particular dust of specified thickness. The hot plate method recommended by the National Materials Advisory Board was followed (Reference 18). The heated surface consisted of a stainless steel plate 200 millimeters in diameter and 20 millimeters thick. The plate was heated by an electrical hot plate, which was controlled by a variable autotransformer. A thermocouple was mounted in the center of the stainless steel plate within 1 millimeter of the upper surface. The junction contacted the stainless steel plate. In the absence of a dust layer, the hot plate could reach 400 °C and could maintain a constant temperature within ± 5 °C. The thermocouple readout was accurate within ± 3 °C. A 2-millimeter diameter Type K thermocouple was used as the dust thermocouple. This thermocouple was placed in the center of the dust sample parallel to the heated surface. The test thermocouple readout was monitored at 1 minute intervals during each test. The ambient temperature, which was measured by a thermometer placed near the hot plate, was maintained at 22-25 °C.

A cavity was formed by placing a 100-millimeter diameter, 12.5-millimeter tall stainless steel ring on the surface of the stainless steel plate. Dust was placed in the cavity and leveled off to the top of the ring to give a 12.5-millimeter thick layer.

The test apparatus was placed under a fume hood and the hot plate was set at the desired temperature and maintained there using the autotransformer. The ring was placed in the center of the stainless steel plate with the test thermocouple in place and was filled with dust. A timer was then started and the test thermocouple was read once a minute.

Ignition was defined as the initiation of combustion in the material under test. The standard test defines ignition temperature as the minimum hot plate temperature causing smoke or a red glow. In all cases, in the experiments reported here, only smoke was observed at ignition; however, a red glow could be observed by breaking up the sample after smoke appeared. The lowest temperature of the hot surface causing ignition for a given dust layer was rounded to the nearest multiple of 10 °C. Note that this standard

method defines the ignition temperature as that of the lowest fixed stainless steel plate temperature causing ignition. It is not the temperature measured with the dust thermocouple. The temperatures determined for the dust are significantly lower than the fixed temperatures. Values measured for the dust are questionable owing to poor contact between the loose, unpacked dust and the thermocouple. If the dust did not ignite within 30 minutes, the test was terminated.

Each test was initiated with a fresh layer of dust at higher and higher temperatures until the ignition temperature was determined. This was followed by another set of tests to verify the ignition temperature to within 10 °C. Times to ignition were measured to ± 2 minutes. All results are reported in Table 38.

2. Sample 2

Sample 2 ignited at approximately 270 ± 5 °C at 12 ± 2 minutes after test initiation. At this point, the measured dust temperature was 210 °C. The ignition time was taken as the time at which smoke emission occurred. If left in contact with the hot plate for a sufficient time, the dust burned completely with the temperature of the dust rising above that of the hot plate. The original sample was cakelike and tended to pack. Care was taken to ensure that the material was not compacted at each trial initiation. During heating, the dust surface cracked and the sample appeared to shrink. Smoke was first noted coming from around the edge of the circular layer. As combustion continued, the sample became semisolid and shrunk to a bowl shape. The burnt sample was covered with a black crust. When broken, it exhibited a gray ash. A distinctive, acrid odor, which appeared to be that of formaldehyde, occurred during heating of this and the other samples.

TABLE 38. LAYER IGNITION TEMPERATURE TEST RESULTS

Fixed surface temp., °C	Trial results	Time to ignition, minutes
Sample 2		
120	no ignition	--
180	no ignition	--
200	no ignition	--
250	no ignition	--
260	no ignition	--
270	ignition	13
270	ignition	11
280	ignition	12
310	ignition	2
310	ignition	3
Bag 1 Material		
120	no ignition	--
180	no ignition	--
200	no ignition	--
250	no ignition	--
260	ignition	20
270	ignition	11
270	ignition	10
310	ignition	3
Bag 6 Material		
200	no ignition	--
250	no ignition	--
260	ignition	19
270	ignition	8
270	ignition	7
310	ignition	2

3. Bag 1 Material

Bag 1 material ignited at 260 ± 5 °C. The ignition time was 20 ± 2 minutes, and the dust temperature at ignition was approximately 180 °C. The sample would burn completely if left in contact with the hot plate for extended periods (longer than 1 hour). When heated, the waste media charred and formed a crust. Smoke was emitted though the surface rather than just around the edge. As occurred for other samples, the material shrunk and became bowl-shaped as combustion continued.

4. Bag 6 Material

The ignition temperature was 260 ± 5 °C and the dust temperature was approximately 180 °C. The time to ignition at a fixed hot plate temperature of 260 °C was approximately 19 ± 2 minutes. Smoke was emitted from around the perimeter. The material burned uniformly from the bottom up. The sample first turned brown and then black.

C. LINEAR BURNING VELOCITIES

1. Procedure

Linear burning velocities were determined by a method which closely followed that used by Cohen and Luft (Reference 19). Dust layers were laid on two fire bricks placed under a fume hood. The hood fan was not activated during a test to avoid the effect of drafts. Layers 15 centimeters long and 3 centimeters wide were placed on the bricks. Dust thicknesses of 0.5, 1.0, and 2.0 centimeters were used. A 10-centimeter length was marked along the layer for determination of burning velocity. The dust was ignited by a gas flame. If ignition was obtained and combustion continued along the length of the layer, the linear burn was timed and the burning velocity was calculated.

2. Sample 2

Four tests were performed on Sample 2: two tests for a layer thickness of 2.0 centimeters, one at a thickness of 1.0 centimeter, and one at a thickness of 0.5 centimeter.

a. Test 1

A dust layer of thickness 2.0 centimeters was exposed to the torch flame for 15 seconds. Ignition was achieved, and the combustion time for the 10.0 centimeter length was 2 hours, 57 minutes. The calculated combustion rate was 0.06 centimeters/minute. The material smoldered and exhibited a red glow. No flame or melting was noted. Not all dust particles were burned and the burn path was irregular.

b. Test 2

The dust layer had a thickness of 1.0 centimeters. Ignition was achieved after exposure to the torch for 15 seconds. The dust smoldered as in Test 1; however, no significant advancement along its length occurred. Self-extinguishment occurred at 18 minutes into the test. The material was reignited and combustion continued for an additional 8 minutes. At that point, self-extinguishment occurred again.

c. Test 3

Ignition was obtained for a 0.5-centimeter thick dust layer, which self-extinguished at 5 minutes. Two reignitions gave burn times of 10 minutes and 8 minutes.

d. Test 4

This test was performed with a 2.0-centimeter thick layer of dust identical to that used for Test 1. The measured combustion rate was 0.05 centimeters/minute. The results of these tests indicate that combustibility increases with layer thickness. Sustained combustion is difficult for layers of 1.0-centimeter thickness and smaller.

3. Bag 1 Material

A 2.0-centimeter thick layer of dust did not sustain combustion. Burning occurred only when the torch was applied. These results indicate that unused media are not as combustible as are PMB wastes. The difference in behavior is probably due to the difference in particle size. Particles of PMB waste are much smaller.

4. Bag 6 Material

Ignition of a 2.0-centimeter thick layer of dust was not achieved for exposures to the torch for periods of 15, 20, or 30 seconds. A 60-second exposure did, however, initiate combustion. The dust smoldered for 10 minutes giving off a very small amount of smoke. The burning did not advance down the length of the dust layer. An additional test was conducted with a 1.0-centimeter thick layer of dust. Ignition was achieved after a 60-second exposure to the torch. Combustion lasted less than 7 minutes, and no advancement of the burning zone occurred.

D. DUST CONCENTRATION MEASUREMENTS

Dust concentration measurements were conducted within ducts at the F-4 aircraft stripping facility at Hill AFB during the period 20-24 July 1987. The measurements were performed by the USAF Occupational and Environmental Health Laboratory. The results, which are presented in Appendix C, indicate that explosion hazards are relatively low except in the bag house.

E. HAZARD ASSESSMENT

Two combustion/explosion hazards are associated with dusts: explosibility and flammability of suspended dust and flammability of dust in a layer. To be explosible, dusts must be flammable or ignitable. The explosibility of dusts is strongly dependent on particle size. Dusts with smaller particle sizes are more hazardous. The maximum pressure generated by an explosion is related to particle size and the amount of turbulence prior to ignition. More turbulence gives a greater hazard. The rate of pressure rise is critical in determining countermeasures to dust explosions. If the rate of pressure rise is too great, vents and pressure sensing devices will not function. In general, countermeasures for minimizing the damage of a dust explosion include keeping the facility small, keeping dust concentrations low, maintaining cleanliness, and housing the facility in a lightweight building, exterior to the main plant if possible, with proper explosion venting. The Bureau of Mines (Reference 17) has recommended the use of venting for blasting facilities.

The problem associated with dust layers is less spectacular but no less damaging. The major concerns are (1) spontaneous ignition and (2) rate of flame spread or smoulder rate. A critical layer, below which combustion cannot be supported, exists. The major hazards in plastic media-blasting environments are poor housekeeping practices and bulk storage areas (waste bin and recirculation bins).

Little work has been performed on fire control for plastic media-blasting booths. Since the blasting booth environment is unusual and since a large increase in the use of plastic media blasting is expected, this omission is surprising. It is recommended fire protection technologists develop a general system for these facilities, particularly for those used for aircraft stripping. Aircraft stripping booths are large and have special requirements since materials peculiar to aircraft are present.

SECTION X

CONCLUSIONS

A. BLASTING WASTE CHARACTERISTICS

1. Metal contaminants in PMB waste are more concentrated in fractions containing the smallest particles. The filter cake from the airborne fines has very high levels of contaminants.

2. Whether a waste fails an EP Toxicity Test is partially determined by the extractability of the various metals from that waste. Lead, chromium, cadmium, and barium are present in sufficient amounts to cause many waste samples to fail the test; however, only cadmium and chromium are extracted efficiently during EP Toxicity Tests on most blasting wastes.

3. Primary PMB waste samples vary widely in particulate size distribution and metal analysis. This variation results from the particular paint on the plane being stripped, the recycling efficiency, and the amount of filter cake mixed in. The variability may also result from variations in blasting procedure.

4. The variability in PMB waste is expected to increase markedly as new types of media are used. The proposed Military Specification for plastic media allows a range of plastic types. This variation makes waste treatment difficult.

B. BLASTING WASTE TREATMENT

1. Because the hazardous and nonhazardous particulates are very close in size, screening cannot efficiently separate the waste into regulated and nonregulated components.

2. The electrostatic separation sometimes gives fractions which differ greatly in metal concentrations; however, the results are erratic and the separation is insufficient to consider this method as a waste treatment method.

3. Air elutriation gives significant cleaning of F-4 residue; however, laboratory studies indicate that efficient separation of hazardous and nonhazardous fractions is not possible. A field study using 55 gallons of residue and commercially available equipment which coupled a cyclone with air elutriation (aerodynamic classification) failed to give satisfactory results.

4. Chemical extraction can remove much of the chromium; however, extraction of cadmium does not appear promising. Moreover, in some cases lead and/or cadmium are solubilized by chemical extraction procedures. Chemical extraction could be valuable for wastes contaminated only with chromium. A major problem with extraction is the generation of metal-containing liquid wastes.

5. Density separation can separate PMB waste into a metal-rich and a metal-depleted fraction. Carbon tetrachloride works very well, giving a sink material containing most of the metal contaminants; however, owing to the toxicity of this material, handling and waste disposal would be difficult. This method would be more attractive for media with lower densities since the range of available liquids increases with decreasing specific gravity requirements. Specific gravity separation appears to be a potentially useful treatment process and should be investigated further.

6. Heating PMB waste at 750 °C to 950 °C with restricted air reduces mass by approximately 80 percent and produces a char which easily passes the EP Toxicity Test. Since heating to these temperatures releases formaldehyde and since this treatment would be at least as difficult to license as incineration, this process does not appear to be a viable treatment method.

7. Encapsulation using standard portland cement appears to be economical for preparing materials which pass an EP Toxicity Test. Encapsulations using other materials give poorer results or are more difficult and expensive to carry out. Cement encapsulation would permit the use of Class B landfills for interim disposal until other, more permanent disposal methods (such as incineration) were developed; however, permitting could be time consuming. The use of encapsulated waste as structural material should be evaluated; however, this does not appear promising at this time, due to concerns about distribution of nominally hazardous waste.

8. A combination of methods may have merit. For example, the ash from incineration could be encapsulated, as could the regulated waste fraction from a density separation.

C. PMB WASTE COMBUSTIBILITY

1. Layers of PMB waste ignite and burn with difficulty. Contact with a surface at approximately 260-270°C is needed for ignition within 30 minutes. An open flame will cause a much faster ignition. The material burns with a glowing, smoldering combustion and low burning velocities of approximately 0.05-0.06 centimeters/minute for a 2-centimeter thick layer. Layers thicker than 0.5 centimeters are needed for significant sustained combustion.

2. Burning PMB waste emits acrid fumes, which appear to contain formaldehyde.

3. Unused plastic media are much less combustible than waste dust. This difference in combustibility is probably due to the difference in average particle size.

SECTION XI
RECOMMENDATIONS

1. Structural and aging properties should be determined for various compositions of cement-encapsulated waste. The results of this testing should be analyzed to evaluate the potential of the resulting product as structural material.

2. A limited pilot-scale field test of encapsulation with portland cement should be performed at the Hill AFB F-4 stripping area. The test should include evaluation of drums as containers, studies of disposal methods, and sampling of material from all drums for EP Toxicity Testing.

3. An expanded project to develop liquid density separation should be considered. Such a project should include research on emission control, handling of liquid wastes, and removal of liquids from blasting wastes. Although the low toxicities and high volatilities of chlorofluorocarbons makes them ideal candidates for investigation as the liquids used in density separations, stratospheric ozone depletion potentials must be considered. Some chlorofluorocarbons have very low ozone depletion potentials.

4. Investigations of incineration methods, to include rotary kiln incinerators, for PMB waste should be performed. This investigation should include determination of destruction efficiency, ash characteristics, and gaseous emissions.

5. The promulgated Toxicity Characteristic Leaching Procedure (TCLP) contains a number of organic chemicals having relatively low allowable levels. Various blasting wastes should be subjected to TCLP testing to ensure that the waste does not fail based on criteria other than extractable metals.

6. The proposed Military Specification for new plastic blasting media should specify limits for EP Toxicity values of all regulated elements.

7. Explosivity and flammability of alternative media, such as methacrylate, should be evaluated.

8. Fire protection technologists should be tasked to develop fire protection systems and specifications for existing and planned aircraft stripping facilities. One basic system could be specified with allowable variations according to specific needs of each facility. The Air Force may benefit from a central focal point for fire and explosion protection for all stripping facilities.

9. Research on alternative non-chromium-containing paints for aircraft should be conducted. One question to be answered is whether chromium-containing conversion coatings alone would provide the corrosion resistance now obtained with chromate primer.

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APPENDIX A
SAMPLES AND ANALYTICAL RESULTS

SAMPLE 0

Early sample from F-4 blasting area, Bldg 223. Received prior to start of project.

SAMPLE 1

Two bags, approximately 4 pounds total. Received from Hill AFB on 22 Feb 86. Probably not representative, since sieve analysis showed 36.6 percent was coarser than 50 mesh.

As-received, average of four samples

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	36.60	63.40
80	31.01	32.39
100	6.71	25.68
140	8.91	16.77
200	5.38	11.39
325	6.86	4.53
Pan	4.01	0.00

Crushed with Bico Pulverizer, average of three samples

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	39.01	60.99
80	33.91	27.08
100	7.24	19.84
140	8.32	11.52
200	4.66	6.85
325	4.13	2.72
Pan	2.13	0.00

"BB-4-1": As-received

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	0.32	13.0, 7.1	<0.05

"BB-1-2": +50 mesh

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	0.19	0.80	<0.05
Lab BU	--	--	--	0.12	1.30	<0.05

"BB-1-1": -100 mesh

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	1.0	19.0	<0.05
Lab BU	--	--	--	0.92	29.4	<0.05

"BB-4-2A": 10% HCl leach. Not a standard EP Tox test.

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	2.4	108.98	0.88

"BB-4-2b": HCl-extracted sample

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab HU	69	2202	280	--	--	--
Lab JE	--	--	--	0.9	2.2	11.0
Lab JE	--	--	--	1.2	<0.05	15.2

SAMPLE 2

Obtained 19 Feb 86 from F-4 blasting booth waste bin, Bldg 223, Odgen ALC. Not representative. Approximately 96.3 percent less than 200 mesh. Appears to be primarily filter cake collected shortly after the cartridge filters in the dust collector were cleaned by a reverse pulse of compressed air. Labeled as "filter cake." Three bags, approximately 12-15 pounds total.

Two-gram sample screened by ATM, Sonic Sifters Division

<u>Sieve Size, microns</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
75	3.7	96.3
45	12.6	83.7
30	14.5	69.2
20	17.6	51.6
15	12.7	38.9
10	17.1	21.8
5	11.6	10.2
Pan	10.2	0.0

"Filter Cake A": Material as received

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab HU	600	2500	1400	--	--	--
Lab JE	--	--	--	18.0	24.89	<0.05

"M10": Double EP extract 1. "M15": Double EP extraction 2. Both Lab WA

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
M10	--	--	--	12.7	29.3	0.4
M15	--	--	--	4.3	2.8	0.2

Moisture content (ASTM 3173-85): 7.78 percent
Ash content (ASTM 3174-82): 10.50 percent
Volatile matter (ASTM 3175-82): 75.58 percent
Carbon by difference (ASTM 3178-84): 13.92 percent
Density of sample: 1.42 g/ml

"P1": PERCOL S-100 with 20% dust (by weight); broken up to pass 3/8 inch screen

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
	--	--	--	0.15	0.75	<0.05

"M5": Acid resistant cement control

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab WA	--	--	--	0.1	4.8	3.9

Encapsulated with Mix "A" acid resistant cement (54.9 percent cement, 45.1 percent PMB waste). No EP tox test. Mixture crumbled at touch

27.5 g cement
13.8 g fly ash
6.2 g bentonite
1.9 g D-65
60.0 g PMB waste
17.5 mL water

Encapsulated with Mix "B" acid resistant cement (63.2 percent cement, 36.8 percent PMB waste)

36.7 g cement
18.3 g fly ash
8.3 g bentonite
2.5 g D-65
38.3 g PMB waste
20.8 mL water

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	0.3	28.8	<0.05

"C-3": Encapsulated with acid resistant cement (76.7 percent cement, 23.4 percent PMB waste)

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	<0.01	12.0	<0.05

"BB": Encapsulated in polyethylene from U. S. Industrial Chemicals. 26 percent PMB waste, 2.8:1 polyethylene to filter cake, broken to pass 3/8 inch screen

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
	--	--	--	0.3	<0.05	<0.05

"Top": Top layer in specific gravity separation using ferric chloride.

"Bottom": Bottom layer

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Top	200	380	400	--	--	--
Bottom	608	434	350	--	--	--

"M500": Charred at 950 °C for 7 minutes

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab WA	--	--	--	0.2	0.3	0.1

Chemical treatment

"M600/M650": Heated to 750 °C. Extracted with 10 percent nitric acid. The liquid was filtered and split; half was used for M700. In the remaining half the pH was raised to 11.0 by addition of NaOH. The liquid was filtered and the filtrate analyzed. "M700/M550": Procedure used was the same as "M650" except for addition of iron(III) chloride equal in weight to the original ash. Analyses by Lab WA.

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
M600/M650	--	--	--	0.3	1.5	29.2
M700/M550	--	--	--	--	1.0	--

Electrostatic separation. "2A": More attracted by field. "2B": Less attracted by field.

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
2A	690	2160	1490	14.7	30.1	<0.2
2B	690	2230	1480	15.5	32.3	<0.2

SAMPLE 3

Collected 27 Mar 86. 1 bag from the blast floor. 1 bag of +50-mesh material returned to the pressure pot input bin. 1 bag of -50-mesh waste from the primary waste bin (vibrator problem caused some +50-mesh media to be present). About 4-5 pounds of each.

SAMPLE 4

Received 11 Apr 86. 3 bags, approximately 12 pounds total. One bag was collected in the primary waste bin and had passed a nominal 50-mesh screening. One bag was collected as return material and had, therefore, been retained by 50-mesh screen. The third bag was unmarked.

"-50A"

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	25.25	73.44
80	34.51	38.93
100	10.41	28.52
140	11.64	16.89
200	6.48	10.41
325	8.03	2.38
Pan	2.38	0.00

"-50B"

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	22.36	78.01
80	33.89	44.68
100	11.06	33.81
140	12.98	21.04
200	8.01	13.16
325	12.58	0.79
Pan	0.80	0.00

-50 mesh, as received

<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
67	625	590	1.08	18.0	<0.2

-50 mesh stirred into a solution of potassium iodide of density 1.5 g/mL, 82 percent of material was in float layer.

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Float	25	150	230	0.38	0.5	<0.2
Sink	67	720	1300	--	--	--

114 g heated at 750°C in the absence of air producing 20.2 g of charred material.

<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
--	--	--	<0.05	<0.2	<0.2

SAMPLE 5

Received from Hill AFB 24 Apr 86, Bldg 223, F-4 blasting area, primary baghouse.

As received, average of two samples

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
20	0.10	99.90
30	2.01	97.89
40	3.71	94.19
50	5.56	88.62
80	24.21	64.41
Pan	64.41	0.0

As received, Rescreened and adjusted for drying losses

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	11.25	88.75
70	20.91	67.84
100	18.52	49.32
140	15.03	34.29
200	10.59	23.83
270	7.28	16.55
400	9.08	7.45
Pan	7.45	0.00

"M+50": +50-mesh fraction

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	0.4	0.75	0.05
Lab WA	--	--	--	nd	1.0	nd
Lab HU	--	--	--	0.35	1.2	<0.2

"M50": -50.+70-mesh fraction

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	1.14	0.014	0.009
Lab WA	--	--	--	0.7	6.8	nd
Lab HU	44	298	--	0.5	7.0	<0.2

"M70": -70.+100-mesh fraction

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	0.75	5.0	<0.05
Lab WA	--	--	--	0.6	6.0	nd
Lab HU	--	--	--	0.45	8.1	<0.2

"M100": -100.+140-mesh fraction

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	1.25	0.035	0.016
Lab WA	--	--	--	1.3	16.2	0.2
Lab HU	75	1304	--	0.90	24.8	<0.2

"M140": -140.+200-mesh fraction

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE (1st)	--	--	--	5.0	20.0	<0.05
Lab JE (2nd)	--	--	--	12	25.55	0.15
Lab WA	--	--	--	1.1	22	<0.5
Lab HU	--	--	--	1.1	28.5	<0.2

"M200": -200.+270-mesh fraction

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	9.0	25.5	0.8
Lab WA	--	--	--	15.5	39	<0.5
Lab HU	--	--	--	17.4	35.5	0.55

"M270": -270,+400-mesh fraction

	<u>Totals. ppm</u>			<u>EP Tox. mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	2.5	17.0	0.03
Lab WA	--	--	--	2.8	24	<0.5
Lab HU	--	--	--	2.93	32.0	<0.2

"M400": -400 mesh-fraction

	<u>Totals. ppm</u>			<u>EP Tox. mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Lab JE	--	--	--	0.6	30.25	0.04
Lab WA	--	--	--	12.4	38	0.5
Lab HU	--	--	--	12.5	37.0	<0.2

Moisture content of -325 mesh fraction: 4.70 percent
Moisture content of -200,+325 mesh fraction: 5.053 percent

Fines removed from 50 by 70 mesh cuts by air elution

	<u>Totals. ppm</u>			<u>EP Tox. mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Clean	35	261	--	--	--	--
Dust	519	1641	--	--	--	--

Fines removed from 100 by 140 mesh cuts by air elution

	<u>Totals. ppm</u>			<u>EP Tox. mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Clean	57	1198	--	--	--	--
Dust	716	2034	--	--	--	--

"11-17": Dried sample of 100 X 140 fraction air-elutriated 1.5 hours and stirred with carbon tetrachloride. About 94 percent of the material floated.

	Totals, ppm			EP Tox, mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
Input	60	1200	1400	0.006	0.12	0.14
Float	40	140	140	0.004	0.014	0.014
Sink	400	17,100	17,200	0.040	1.71	1.72

BAG 1

New U. S. Technology Corp. POLYPLUS 30 X 40 mesh plastic blasting media (labeled 20 X 30) collected 18 Nov 86 at Hill AFB.

BAG 2

12 X 16 mesh plastic blasting media collected 18 Nov 86 from Hill AFB.

BAG 3

Screened media from surge bin above pressure pots, collected 18 Nov 86 from Hill AFB F-4 stripping area, Bldg 223.

BAG 4

Floor material from blasting booth, collected 18 Nov 86 from Hill AFB F-4 stripping area, Bldg 223.

BAG 5

Material from 45 degree ledge below observation window, collected 18 Nov 86 from Hill AFB F-4 stripping area, Bldg 223.

BAG 6

Primary waste from bins under primary dust filter, collected 18 Nov 86 from Hill AFB F-4 stripping area, Bldg 223.

As received

<u>Sieve Size</u>	<u>Retained. %</u>	<u>Cumulative Passing. %</u>
30	4.73	95.3
50	12.52	82.8
60	3.58	79.2
70	8.86	70.3
80	8.05	62.3
100	12.49	49.8
140	14.43	35.3
200	9.29	26.0
270	8.34	17.7
400	7.62	10.1
Pan	9.84	0.0

<u>Sieve Size</u>	<u>Retained. %</u>	<u>Cumulative Passing. %</u>
50	17.73	82.27
100	32.09	50.18
200	23.37	26.81
400	13.92	12.89
Pan	12.31	0.00

Bag 6. "000": as received. "50": +50 mesh fraction. "100": -50.+100 mesh fraction. "200": -100.+200 mesh fraction. "400A": -200.+400 mesh fraction. "400": -400 mesh fraction

	<u>Totals. ppm</u>			<u>EP Tox. mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
000	152	1700	790	1.70	28.1	<0.2
50	28	80	60	0.23	1.5	<0.2
100	34	700	420	0.40	13	<0.2
200	52	1900	1020	1.07	52	<0.2
400A	162	3200	1320	3.71	80	<0.2
400	770	2720	1260	6.9	68	<0.2

Air elutriation of 60 g of material. "000B": Bottom 32.45 g. "000T": Top 23.82 g

	<u>Totals. ppm</u>			<u>EP Tox. mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
000B	48	800	388	0.35	19.6	<0.2
000T	336	2400	1070	2.74	48.4	<0.2

Air elutriation of 51.81 g of -80.+100 mesh fraction. "80B": Bottom 42.70 g.
"80T": Top 7.41 g

	Totals. ppm			EP Tox. mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
80B	42	660	466	--	--	--
80T	62	4140	1890	--	--	--

Water settling of -100.+140 fraction. "140B": Bottom. "140T": Top

	Totals. ppm			EP Tox. mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
140B	66	1340	1000	--	--	--
140T	75	1580	918	--	--	--

Wet screening of +140.-200 fraction

"WS270": On-screen cut screened with water + surfactant to 270 mesh.
 "200B": Top from water settling of sample passing 270 mesh. "200T": Bottom
 from water settling of sample passing 270 mesh.

	Totals. ppm			EP Tox. mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
WS270	554	950	920	--	--	--
200B	100	2300	1500	--	--	--
200T	63	1440	740	--	--	--

Freon-113 specific gravity separation. Total sample was 39.2 g. Top layer:
9.35 g. middle layer: 5.29 g. bottom layer: 19.19 g

	Totals. ppm			EP Tox. mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
Top	248	2430	1390	1.97	64	<0.5
Middle	131	1480	885	1.00	23	<0.5
Bottom	191	1190	660	1.04	20.5	<0.5

Electrostatic separation. "6A": More attracted into field. "6B": Less
attracted

	Totals. ppm			EP Tox. mg/L		
	Cd	Cr	Pb	Cd	Cr	Pb
6A	115	790	470	1.0	17.1	<0.2
6B	100	2060	1110	2.0	44.0	<0.2

"Char A": Charred 500 °C for 15 min then raised 750 °C for additional 15 min. "Char B": Same as "Char A" except glass wool filter placed in retort neck

	<u>Totals, ppm</u>			<u>EP Tox. mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Char A	147	2760	1590	0.05	0.2	0.30
Char B	618	<8	<40	--	--	--

"PC-1": Waste/kiln dust cement, 50/50 by weight

	<u>Totals, ppm</u>			<u>EP Tox. mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
	--	--	--	<0.03	4.3	0.39

Flammability studies

0.2 cm thickness - did not smolder across
 0.5 cm thickness - did not smolder across
 1 cm thickness - did not smolder across
 2 cm thickness - did not smolder across

BAG 7

Secondary waste (suspended dust filtered from air), from Bldg 223, F-4 aircraft; 18 Nov 1986.

BAG 8

New 100-mesh garnet, collected 18 Nov 86 from Hill AFB, Bldg 505, gun parts and landing gears.

BAG 9

New 180-mesh Norton Dynablast aluminum oxide/titanium oxide, collected 18 Nov 86 from Hill AFB, Bldg 505, gun parts and landing gears.

BAG 10

Waste garnet, collected 18 Nov 86 from Hill AFB, Bldg 505, gun parts and landing gears.

As received

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	0.05	99.95
70	0.09	99.86
100	0.66	99.20
140	5.95	93.25
200	15.42	77.83
230	5.44	72.39
270	16.31	56.08
325	5.15	50.93
400	13.31	37.62
Pan	40.02	0.0

"GW-1": Input sample, "GC-1": Encapsulated in 50/50 by wt cement kiln dust by Conservation Services, Inc.

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
GW-1	906	102	28	45	<0.2	<0.2
GC-1				<0.03	<0.2	0.30

BAG 11

Waste aluminum oxide/titanium oxide, collected 18 Nov 86 from Hill AFB, Bldg 505, gun parts and landing gears.

As received

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	0.04	99.96
70	0.13	99.83
100	0.17	99.66
140	0.77	98.89
200	20.14	78.75
230	14.17	64.58
270	35.98	28.60
325	4.77	23.83
400	8.46	15.37
Pan	15.41	0.0

Electrostatic separation. "11I": As received. "11A": More attracted to electrostatic field. "11B": Less attracted

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
11I	510	50	36	28	<0.2	<0.2
11A	--	--	--	28	<0.1	<0.1
11B	--	--	--	30	<0.1	<0.1

BAG 12

Garnet collected 18 Nov 86 from metal plates in blasting booth (partly worn), Hill AFB, Bldg 505, gun parts and landing gear.

BAG 13

PMB waste from booth 412, Bldg 507, landing gears, collected 18 Nov 86 from Hill AFB.

As received

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	0.12	99.88
70	1.94	97.94
100	9.22	88.72
140	20.39	68.33
200	13.96	54.37
230	32.04	22.33
270	8.98	13.35
325	5.76	7.59
400	5.64	1.95
Pan	1.94	0.0

Electrostatic separation. "13I": As received. "13A": More attracted to electrostatic field. "13B": Less attracted

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
13I	5070	159	28	202	1.40	0.23
13A	--	--	--	180	1.21	<0.1
13B	--	--	--	210	1.39	<0.1

BAG 14

PMB and walnut shell waste collected 18 Nov 86 from Booth 416, Bldg 507, Hill AFB, landing gears.

As received

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	13.31	86.69
70	7.56	79.13
100	8.70	70.43
140	13.22	57.21
200	19.02	38.19
230	17.03	31.16
270	9.40	21.76
325	4.09	17.67
400	8.61	9.06
Pan	9.01	0.0

Electrostatic separation. "PW-1": As received. "14A": More attracted to electrostatic field. "14B": Less attracted

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
PW-1	290	160	40	13.2	3.10	0.45
14A	--	--	--	3.5	0.88	<0.1
14B	--	--	--	4.0	1.36	<0.1

BAG 15

Plastic and walnut shell collected 18 Nov 86 from Hill AFB, Booth 416 (floor), Bldg 507, landing gear.

BAG 16

Waste glass beads collected 18 Nov from Hill AFB, Bldg 507, landing gears.

BAG 17

Mixture off floor (agricultural, garnet, plastic), collected 18 Nov 86 from Hill AFB, Bldg 847, missile trailers.

Bag 18

Mixed wastes from bins, collected 18 Nov 86 from Hill AFB, Bldg 847, missile trailers.

As received

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	17.07	82.93
70	8.32	74.61
100	12.97	61.64
140	15.04	46.60
200	18.84	27.76
230	7.33	20.43
270	12.80	7.63
325	1.98	5.65
400	2.07	3.58
Pan	2.93	0.0

Electrostatic separation. "MTW-1": As received, "18A": More attracted to electrostatic field, "18B": Less attracted)

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
MTW-1	149	450	625	5.88	4.55	3.5
18A	--	--	--	4.1	<0.1	0.10
18B	--	--	--	3.2	0.15	<0.1

BAG 19

Material off floor, partially recycled, collected 18 Nov 86 from Hill AFB, Bldg 205, wing folds

BAG 20

Waste from bin, collected 18 Nov 86 from Hill AFB, Bldg 205, wing folds

As received

<u>Sieve Size</u>	<u>Retained, %</u>	<u>Cumulative Passing, %</u>
50	32.63	67.37
70	17.03	50.34
100	17.64	32.70
140	14.11	18.59
200	8.82	9.77
230	2.16	7.21
270	2.81	4.80
325	0.80	4.00
400	0.92	3.08
Pan	2.85	0.0

Thermal encapsulation, no binder.

"ET-3": Input sample; "TE-1": 30 min at 250 °C; "TE-2": 30 min at 150 °C;
 "TE-3": 30 min. at 175 °C; "TE-4": 30 min. at 200 °C; "TE-5": 250 °C; "TE-
 6": 275 °C; "TE-7": 300 °C; "TE-8": 325-375 °C; "TE-10": 30 min at 350 °C;
 "TE-11": 30 min at 525 °C

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
EET-3	150	585	580	1.8	9.6	<0.2
TE-1	--	--	--	4.84	2.49	0.62
TE-2	--	--	--	1.60	9.50	<0.2
TE-3	--	--	--	2.74	8.36	<0.2
TE-4	--	--	--	2.78	7.40	<0.2
TE-5	--	--	--	5.90	2.70	0.53
TE-6	--	--	--	5.30	3.05	0.80
TE-7	--	--	--	5.30	4.40	2.00
TE-8	--	--	--	3.90	3.95	4.10
TE-10	--	--	--	2.80	0.18	1.30
TE-11	--	--	--	1.85	4.20	3.20

Extraction.

"EET-1": First extract from enhanced EP tox (extracted for 2-1/2 days at 118 °F). "EET-2": Standard EP tox test using leached solids from EET-1; "EET-4": Doubly leached solid (left from test EE-2)

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
EET-1	--	--	--	2.8	8.9	<0.2
EET-2	81	470	520	3.3	0.8	1.1
EET-4	59	525	720	--	--	--

Acrylic encapsulation.

"PE-2": 10 percent acrylic, pellets pressed and then heated (no EP toxicity performed). "PE-3": 15 percent acrylic, pellets pressed and then heated. "PE-4": 10 percent acrylic, heating only. "PE-5": 15 percent acrylic, heating only. No EP toxicity performed on any of the preceding materials, which disintegrated. "PE-7": 15 percent acrylic, heated at 250 °C for 30 min (charred slightly, material was slightly sticky). "PE-8": 15 percent acrylic, heated at 210 °C for 30 min (resultant material charred slightly and was slightly sticky). "PE-9": 15 percent acrylic, heated at 170 °C and pressed at the same time (initially solid, intact pellets fell apart during EP tox test).

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
PE-7	--	--	--	4.6	2.68	0.79
PE-8	--	--	--	3.8	2.48	0.42
PE-9	--	--	--	1.5	7.60	0.10

"EE-6": 10 percent Scotchweld 2216 B/A epoxy mixture heated for 2 hours at 75 °C to cure

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
	--	--	--	3.9	0.54	0.58

Cement encapsulation

"Control 1": Rich mixture, 1 part cement, 1-1/2 parts sand, 3 parts stone, 0 parts PMB waste (100/150/300/0). "Control 2": Same ratio as Control-1 with less water. "CR-1": 100/150/250/50 cement mixture (41.33 g of waste to 70 mL water). "CR-2": 100/150/200/100 cement mixture (81.46 g of waste to 82 mL water). "CR-3": 100/150/150/150 cement mixture (127.99 g of waste to 94 mL water). "CR-4": 100/150/100/200 cement mixture (165.46 g of waste to 111 mL water). "CS-1": 100/100/300/50 cement mixture (45.48 g of waste to 63 mL water). "CS-2": 100/50/300/100 cement mixture (88.93 g of waste to 67 mL water). "CS-3": 100/0/300/150 cement mixture (129.53 g of waste to 75 mL water). "CCombo-1": 100/100/250/100 cement mixture (85.45 g of waste to 74 mL water). "CCombo-2": 100/50/200/200 cement mixture (169 g of waste to 100 mL water).

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Control 1	--	--	--	<0.1	0.05	<0.5
Control 2	--	--	--	<0.1	<0.01	<0.5
CR-1	--	--	--	<0.1	0.28	<0.5
CR-2	--	--	--	<0.1	0.55	<0.5
CR-3	--	--	--	<0.1	0.90	<0.5
CR-4	--	--	--	<0.1	1.00	<0.5
CS-1	--	--	--	<0.1	0.35	<0.5
CS-2	--	--	--	<0.1	0.50	<0.5
CS-3	--	--	--	<0.1	1.25	<0.5
CCombo 1	--	--	--	<0.1	0.65	<0.5
CCombo 2	--	--	--	<0.1	1.40	<0.5

PAINT FLAKES

"PF-1": Paint flakes, received 6 Nov 86

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
	8	13,600	12,700	0.06	216	<0.2

ROTEX SAMPLES

Two 5-gallon cans (approximately 100 pounds) of F-4 waste collected January, 1987, and sent directly to Rotex, Inc., for wet-sieve sizing. Only dry screening was attempted, owing to a feeling that screen blinding would make wet sieve sizing unfeasible on a continuous basis.

Carbon tetrachloride float/sink on -50.+60 Rotex-screened material

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>			<u>Weight %</u>
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>SiO₂</u>
Float	22	148	--	--	--	--	0.04
Sink	180	6290	--	--	--	--	2.44

Carbon tetrachloride float/sink on -60-mesh Rotex-screened material

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>			<u>Weight %</u>
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>SiO₂</u>
No float/sink	--	--	--	1.18	23.5	<0.5	--
No float/sink	--	--	--	1.23	24.0	<0.5	--
Float	30	314	--	--	--	--	0.35
Sink	650	5550	--	--	--	--	2.78

FISHER-KLOSTERMAN SAMPLES

A 55-gallon drum of blasting media residue from the primary waste bin at the F-4 stripping facility, Hill AFB, was shipped to Fisher-Klosterman for classification. Run 3 was analyzed.

"FC-1": Input material, "FC-2": 24.26 percent > 40 mesh, "FC-3": 47.46 percent > 70 mesh, "FC-4": 28.2 percent < 70 mesh (pan)

	<u>Totals, ppm</u>			<u>EP Tox, mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
FC-1	88	989	--	0.37	37	--
FC-2	20	163	--	0.07	5	--
FC-3	18	329	--	0.07	16	--
FC-4	31	869	--	0.14	32	--

STANDARD

"M450": Standard to check results of laboratories

	<u>Totals, ppm</u>			<u>EP Tox. mg/L</u>		
	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
As prepared	--	--	--	1.25	11.5	0.5
Lab JE	--	--	--	52.4	32.0	28.3
JE revised	--	--	--	0.7	8	0.44
Lab WA	--	--	--	1.2	14	<0.5
Lab HU	--	--	--	1.25	11.0	0.49

APPENDIX B

COMPARISON OF ANALYTICAL LABORATORIES

Metal analyses were performed at four laboratories: the Air Force Weapons Lab (Lab WA), the contractor's laboratory (Lab HU), and two local commercial laboratories (JE and BU). Observed variations in data for analyses of the same samples made it necessary to compare laboratories. In this appendix is a comparison of data for laboratories WA, HU, and JE.

Variability analytical results for the liquids from Extraction Procedure Toxicity testing increased the difficulty of finding if certain size fractions could pass this test. Table B-1 presents some results obtained from laboratories JE, WA, and HU. For an example of the erratic results see the chromium concentrations reported from aliquots of the same liquid EP Toxicity extracts for the -110,+140 fraction of Sample 5 in Table B-1. The three data points have a mean of 13.7 mg/L, and an unbiased estimate of standard deviation (N-1 weighting) of 12.6 mg/L. In this case the 90 percent confidence interval for the true value of the chromium concentration is between 4.4 and 23.0 mg/L. Without additional information about the laboratories, such a statistic is almost useless.

It is difficult to justify discarding one number out of three when independent information about the average range or variance of data is not known. For example, consider the cadmium concentration values of 5.0, 1.1, and 1.1 mg/L for the -140,+200 fraction in Table B-1. From the range, which is a good estimator of standard deviation for small samples, the standard deviation is estimated at 2.04 mg/L. There is only an 80 percent chance that a value of 5.0 mg/L is not part of the distribution of laboratory results which would be obtained if analyses were performed by many laboratories.

TABLE B-1. COMPARISON OF LABORATORY ANALYSES OF SAMPLE 5.

Fraction	Concentration, mg/L								
	Lead			Cadmium			Chromium		
	JE	WA	HU	JE	WA	HU	JE	WA	HU
+50	0.05	nd ^a	<0.2	0.4	nd	0.35	0.75	1.0	1.2
-50,+70	0.009	nd	<0.2	1.14 ^b	0.7	0.5	0.014 ^b	6.8	7.0
-70,+100	<0.05	nd	<0.2	0.75	0.6	0.45	5.0	6.0	8.1
-100,+140	0.016	0.2	<0.2	1.25 ^b	1.3	0.9	0.035 ^b	16.2	24.8
-140,+200	<0.05	<0.5	<0.2	5.0 ^b	1.1	1.1	20.0	22.	28.5
-200,+270	0.8	<0.5	0.55	9.0	15.5	17.4	25.5	39.	35.5
-270,+400	0.03	<0.5	<0.2	2.5	2.8	2.93	17.0	24.	32.0
-400	0.04	0.5	<0.2	0.6 ^b	12.4	12.5	30.25	38.	37.0

^aNot detected.

^bThese values were too far out of range to be included in analysis.

Tables B-2 and B-3 contain an analysis of variance calculation for both laboratories and samples for the four fractions with the largest amount of leached chromium reported in Table B-1. The numbers are coded by subtracting a number close to the mean value of all the data. Then, for the row sum of squares, the rows are summed, these sums are squared, the squares are added, and the result is divided by the number of items in each row. Similarly, the columns are summed, these sums are squared, the squares are added, and the result is divided by the number of items in each column. The total sum of squares is the sum of the squares of each individual item. The

correction factor, to be subtracted from the sums of squares, is the sum of all the items squared, divided by the number of items.

The row degrees of freedom is equal to the number of rows (r) minus 1. The column degrees of freedom is the number of columns (c) minus 1. The residual degrees of freedom is equal to $(r-1)(c-1)$. The residual sum of squares is equal to the corrected total sum of squares minus the corrected row sum of squares minus the corrected column sum of squares.

In Table B-2, the variation due only to difference among rows (size fractions) is significant, and the variation due only to the differences among laboratories (columns) is also significant. The contribution to variability due to laboratory JE is suspected of being the major factor. Therefore, in Table B-3, only laboratories WA and HU are compared. This time, the variability among laboratories is not significant. Laboratories WA and HU are statistically the same. The variance due to sample differences drops to about the 0.1 level of confidence. The random variability is so great that there is only about a 90% chance that the four samples are different from each other in chromium content.

Since laboratory JE appears to be different from the other two laboratories, data reported by this laboratory is questionable and should not be given much weight. Data obtained on carefully prepared identical standard solutions show that laboratories WA and HU give reliable results; however, results from laboratory HU are closer to the correct values (see Section V).

TABLE B-2. TWO-WAY ANALYSIS OF VARIANCE FOR THREE LABORATORIES

Sample ^a	Laboratory			Sums
	JE ^b	WA	HU	
1	-9	-7	-0.5	-16.5
2	-3.5	10	6.5	13
3	-12	-5	3	-14
4	1.25	9	8	18.25
Sums	-23.25	7	17	

Row sum of squares	323.44
Column sum of squares	219.64
Total sum of squares	609.31
Correction factor ^c	0.047

		Degrees of freedom	Mean square	Variance ratio
Row sum of squares	323.393	3	107.8	9.76
Column sum of squares	219.593	2	109.8	9.94
Residual sum of squares	66.277	6	11.05	
Total sum of squares	609.277			

Row variance significant around 0.01 level

Column variance significant at 0.025 level

^aLab results coded by subtracting 29.0.

^bRevised data used for laboratory JE.

^cCorrection factor is $(\text{sum of items})^2 / (\text{number of items})$

TABLE B-3. TWO-WAY ANALYSIS OF VARIANCE FOR TWO LABORATORIES

Sample ^a	Laboratory		Sums
	WA	HU	
1	-10.0	-3.5	-13.5
2	7.0	3.5	10.5
3	-8.0	0.0	-8.0
4	6.0	5.0	11.0
Sums	-5.0	5.0	

Row sum of squares	328.75
Column sum of squares	12.5
Total sum of squares	298.5
Correction factor ^b	0.047

		Degrees of freedom	Mean square	Variance ratio
Row sum of squares	238.75	3	79.58	5.05
Column sum of squares	12.5	1	12.5	0.794
Residual sum of squares	47.25	3	15.75	
Total sum of squares	298.5			

Row variance significant around 0.1 level

Column variance significant only at 0.5 level

^aLab results coded by subtracting 32.0.

^bCorrection factor is $(\text{sum of items})^2 / (\text{number of items})$.

APPENDIX C

USAF OEHL DUST CONCENTRATION MEASUREMENTS

DATE: December 23, 1987

SUBJECT: Consultative Letter 87-159EQ0086MAB, Particle Sizing in Exhaust Ducts of Plastic Media Blasting (PMB) Operations, Hill AFB UT

TO: HQ AFLC/SGP

1. Introduction: We have completed particle size analysis and dust concentration determinations on those ducts providing exhaust ventilation to the PMB room (used for stripping F-4 aircraft) and the PMB booth (used for stripping F-4 aircraft parts) in building 223 and 220, respectively. The USAFOEHL developed this project for AFLC/SGP so that these data could be supplied to those agencies tasked with determining whether or not an explosion hazard exists in PMB operations.

2. Background:

a. Because of a decrease in the ability of chemical strippers to remove high technology coatings and the high cost of treating the large amount of liquid hazardous waste generated during stripping, alternatives to chemical stripping were sought. One of these, PMB, was initiated at Hill AFB to demonstrate a technology which would allow paint removal but with a significant reduction in hazardous waste generation. Due to the success of this prototype operation, both in economic savings and hazardous waste reduction, the Hill facility has been used as a production facility since 1986 and the same technology is being implemented throughout the Air Force.

b. As with any new system, problem areas are identified which require further investigation and research to correct. One such area associated with PMB concerns health and safety, specifically explosion hazards and dust irritability and toxicity. Since large amounts of dust are generated during a PMB operation, HQ AFLC/SGP expressed concern as to the explosion hazard posed by the particle sizes and concentration found in the exhaust systems as well as any health problems posed by the chemical makeup of the dust itself. We were asked to develop a sampling strategy and carry out a sampling program to determine: (1) the size distribution and concentration of the dust found in the PMB exhaust system, and (2) the chemical makeup of the dust on a size related basis.

3. Survey Personnel:

Maj James Garrison, USAFOEHL/ECQ
Capt Tim Fagin, USAFOEHL/ECQ
Capt Mary Daly, USAFOEHL/ECQ
AIC Donald Johnson, USAFOEHL/ECQ

4. Personnel Contacted:

Lt Col Phillip Brown, USAF Hosp Hill/SGPB
Mr. Willert Farrell, USAF Hosp Hill/SGPB
Mr. Dick Stjefkin, USAF Hosp Hill/SGPB
Mr. Tom Byers, OO-ALC/MANPGW
Mr. J. D. Christianson, OO-ALC/MANPGW

5. Methods and Results:

a. Particle sampling was conducted using an Anderson Mark III particle sizing stack sampler. The Mark III is an in-stack 8-stage cascade impactor which measures the size distribution of particles in the gas stream as well as the total particulate mass concentration. This sampler was used in conjunction with the standard Environmental Protection Agency Method 5 sampling train described in Appendix A to Title 40, Code of Federal Regulations, Part 60. Three impactor runs were accomplished on each of the three ducts tested. Sampling locations were at 25%, 50% and 75% of the respective duct diameter and cyclonic flow determinations were made during the velocity traverse prior to sampling. A precollector was used on the impactor to collect all particles with an aerodynamic mass median diameter (MMD) of 14 μm (micrometers) or larger. Our analysis, therefore, involved those particles with a MMD less than 14 μm (those particles collected on the stages of the impactor).

b. Results are as follows:

Note: - mg/acm = milligrams per actual cubic meter

- Results are an average for the three runs and only for particles with MMD less than 14 μm except for the largest particle found in the duct and total mass.

(1) Bldg 223, Floor Exhaust

MMD: 8.2 μm
Geometric standard deviation: 3.0
Largest particle in duct, measured under microscope: 800 μm
Total mass concentration in duct: 3908 mg/acm
% of total mass less than 14 μm : 1.3%

(2) Bldg 223, Ceiling Exhaust

MMD: 5.3 μm
Geometric standard deviation: 3.2
Largest particle in duct, measured under microscope: 25 μm
Total mass concentration in duct: 59 mg/acm
% of total mass less than 14 μm : 34%

(3) Bldg 220, Exhaust to Baghouse

MMD: 8.1 μm

Geometric standard deviation: 3.6

Largest particle in duct, measured under microscope: 700 μm

Total mass concentration in duct: 444 mg/acm

% of total mass less than 14 μm : 12%

6. Conclusions and Recommendations:

a. The data generated from this sampling project follow a pattern that was expected with relation to MMD, mass concentration and % of total mass less than 14 μm for each of the exhaust systems. The PMB operation in Bldg 223 has two separate exhaust systems, one in the floor and the other in the ceiling. We expected to see a marked difference in particle diameter and mass concentration since the floor system picks up beads as well as the large coating particles falling from the mechanical blasting. The larger percentage of smaller particles in the ceiling exhaust was due to the fact that suspended particles are exhausted through this system and the overall particle diameter size range is small compared to the floor system. The results from the PMB operation in Bldg 220 fell in between the values obtained for Bldg 223 because it was a smaller operation (one person as compared to 2 or 3 in Bldg 223) and the duct system exhausted the entire room, picking up the larger material as well as the suspended particulate matter.

b. This project was undertaken for the specific purpose of supplying particulate and dust concentration data to HQ AFESC/RDVS. RDVS has the New Mexico Engineering Research Institute, University of New Mexico (Dr Bob Tapscott) under contract to investigate disposal of bead blast residue, use of other types of blasting media, and hazards associated with dust generated from the blasting operation. Our findings will be provided to RDVS so that it can be made available to the contractor in order to further research in the area of explosion hazards. A more detailed review of this data along with a chemical analysis of the particulate matter collected in the impactor will be provided in a USAFOEHL report in the near future.